The Economic Importance of the Bristol Bay Salmon Industry

prepared for the

Bristol Bay Regional Seafood Development Association

by

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EXECUTIVE SUMMARY

By any measure, the Bristol Bay sockeye salmon fishery is very large and valuable. It is the world's most valuable wild salmon fishery, and typically supplies almost half of the world's wild sockeye salmon. In 2010, harvesting, processing, and retailing Bristol Bay salmon and the multiplier effects of these activities **created $1.5 billion** in output or sales value across the United States.

In 2010, Bristol Bay salmon fishermen harvested 29 million sockeye salmon worth $165 million in direct harvest value alone. That represented 31% of the total Alaska salmon harvest value, and was greater than the total value of fish harvests in 41 states. Salmon processing in Bristol Bay increased the value by $225 million, for a total first wholesale value after processing of $390 million. The total value of Bristol Bay salmon product exports in 2010 was about $250 million, or about 6% of the total value of all U.S. seafood exports.

In 2010, the Bristol Bay sockeye salmon fishery supported 12,000 fishing and processing jobs during the summer salmon fishing season. Measuring these as year-round jobs, and adding jobs created in other industries, the Bristol Bay salmon fishery created the equivalent of almost 10,000 year-round American jobs across the country, and brought Americans $500 million in income. For every dollar of direct output value created in Bristol Bay fishing and processing, more than two additional dollars of output value are created in other industries, as payments from the Bristol Bay fishery ripple through the economy. These payments create almost three jobs for every direct job in Bristol Bay fishing and processing.

United States domestic consumption of Bristol Bay frozen sockeye salmon products has been growing over time as a result of sustained and effective marketing by the industry, new product development and other factors. This growth is likely to continue over time, which will result in even greater output value figures for the industry's economic impacts across the U.S.

The economic importance of the Bristol Bay salmon industry extends far beyond Alaska, particularly to the West Coast states of Washington, Oregon and California.

Bristol Bay fishing boats

- About one-third of Bristol Bay fishermen and two-thirds of Bristol Bay processing workers live in West Coast states.
- Almost all major Bristol Bay processing companies are based in Seattle.
- Most of the supplies and services used in fishing and processing are purchased in Washington state.
- Significant secondary processing of Bristol Bay salmon products occurs in Washington and Oregon.

The economic importance of the Bristol Bay salmon industry goes well beyond the value, jobs, and income created by the fishing and processing which happens in Bristol Bay. More value, jobs and income are created in *downstream industries* as

Bristol Bay salmon are shipped to other states, undergo further processing, and are sold in stores and restaurants across the United States. Still more jobs, income and value are created in other industries through *multiplier impacts* as Bristol Bay fishermen and processors and downstream industries purchase supplies and services, and as their employees spend their income.

Economic Impacts of the Bristol Bay Salmon Industry in 2010

Annual average employment: 9,800 jobs	Output value: $1.5 billion	Income: $500 million
Fishing & processing in Bristol Bay		
12,000 seasonal jobs (=2,000 annual jobs)	$390 million	$140 million
Shipping, secondary processing & retailing after Bristol Bay		
1,000 jobs	$110 million	$40 million
Multiplier impacts in other industries		
6,800 jobs	$970 million	$320 million

Overview of the Bristol Bay Salmon Industry

Bristol Bay is located in southwestern Alaska. Each year tens of millions of sockeye salmon return to spawn in the major river systems which flow into Bristol Bay. The large lakes of the Bristol Bay region provide habitat for juvenile sockeye salmon during their first year of life.

A Bristol Bay salmon fisherman

For well over a century, Bristol Bay salmon have supported a major salmon fishing and processing industry. Most of the harvest occurs between mid-June and mid-July. At the peak of the fishing season, millions of salmon may be harvested in a single day.

Only holders of limited entry permits (issued by Alaska's state government) and their crew are allowed to fish in Bristol Bay. There are permits for two kinds of fishing gear: drift gillnets (operated from fishing boats) and set gillnets (operated from shore). There are approximately 1,860 drift gillnet permits and approximately 1,000 set net permits. Drift gillnet permits average much higher catches and account for most of the total catch. About one-third of the permit holders are from West Coast states.

Bristol Bay Salmon Industry Permit Holders, by State of Residence, 2010

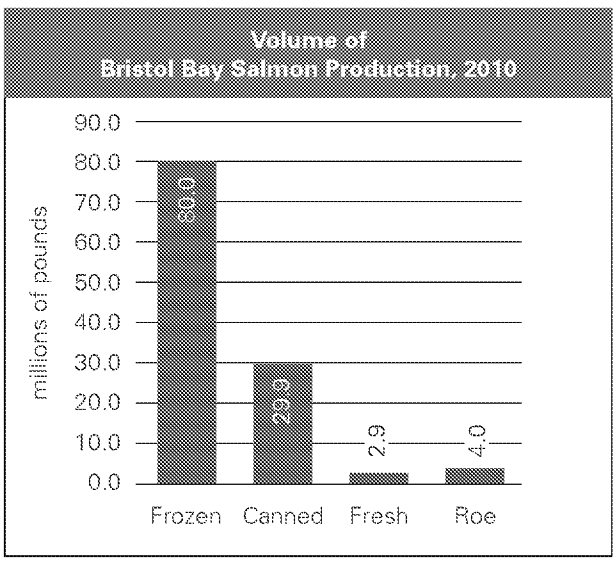
Permit Type	Alaska	Washington	Oregon	California	Other States & Countries	Total
Drift Gillnet	845	642	98	109	156	1,850
Set Gillnet	629	127	38	34	99	927
Total	1,474	769	136	143	255	2,777

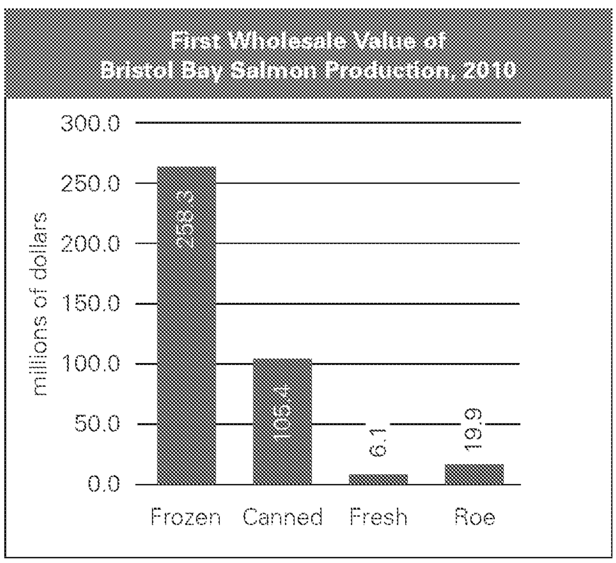
For each permit holder, who is usually a captain, there are typically two to three additional crew members. About 7,000 fishermen fished in Bristol Bay in 2010.

The Bristol Bay salmon harvest is processed by about 10 large processing companies and 20 smaller companies employing about 5,000 processing workers at the peak of the season in both land-based and floating processing operations. Most of the workers are from other states and live in bunkhouse facilities at the processing plants.

Bristol Bay salmon are processed into four major primary products: frozen salmon, canned salmon, fresh salmon, and salmon roe. Frozen salmon includes both headed and gutted (H&G) salmon as well as salmon fillets.

Frozen and canned salmon account for most of the volume and value of Bristol Bay salmon production.

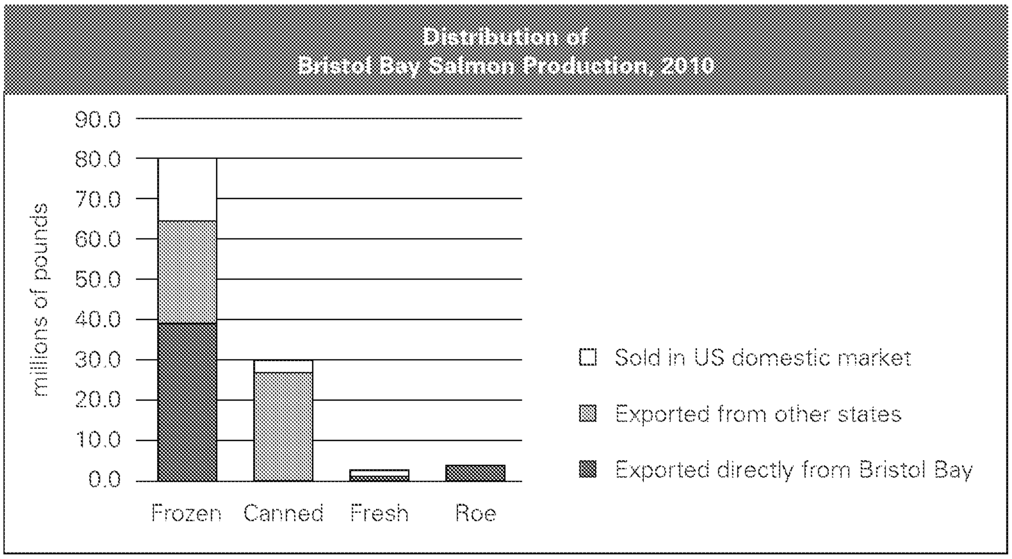




About half of Bristol Bay frozen salmon is exported directly from Bristol Bay, primarily to Japan and China. Most of the remaining frozen salmon is shipped to Washington state where much of it is repackaged and/or reprocessed into secondary products such as fillets, portions and smoked salmon. Some of these products are exported while the rest are sold in the US domestic market.

Bristol Bay canned salmon is shipped to warehouses in Washington and Oregon where it is stored, labeled, and sold by processors over the course of the year, mostly to the United Kingdom and other export markets.

The total value of Bristol Bay salmon product exports in 2010 was about $252 million, or about **6% of the total value of all U.S. seafood exports.**



The value of Bristol Bay salmon increases at each stage in the distribution chain. Because a large share is exported, most of the increase in value in the United States occurs in Bristol Bay fishing and processing. About one-fifth of the total increase in value occurs in later stages of the distribution chain.

Containers for shipping Bristol Bay salmon products

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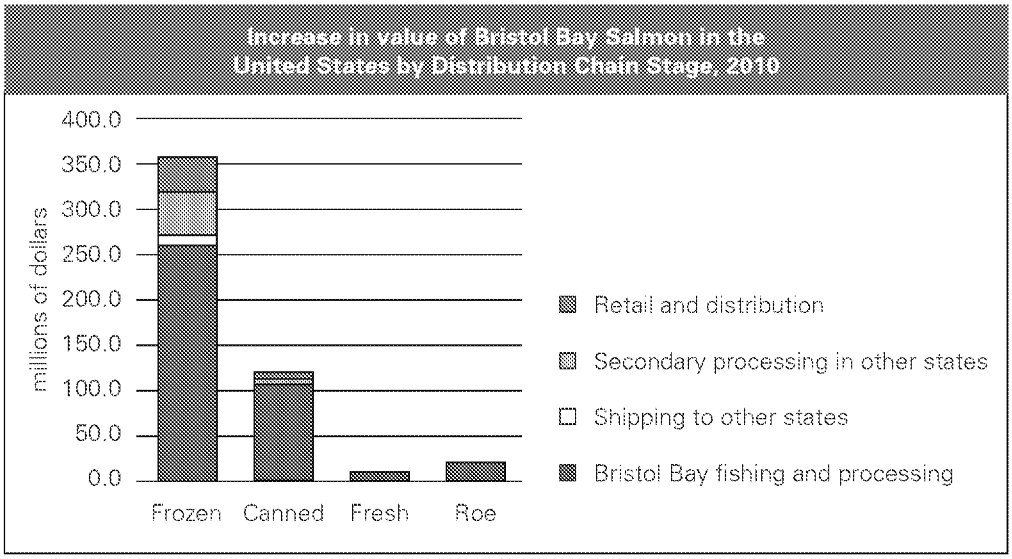


Economic Impacts of the Bristol Bay Salmon Industry

Economic impacts of the Bristol Bay salmon industry are the jobs, income and output value created by the fishery—or the jobs, income and output value that would not exist if the industry did not exist. Economic impacts include:

» *Direct economic impacts:* Jobs, income and output value in businesses directly involved in harvesting, processing, and retailing Bristol Bay salmon.

» *Multiplier economic impacts:* Jobs, income and output value created in other industries as Bristol Bay fishermen, processors and downstream industries purchase supplies and services, and as their employees spend their income.

We estimated both direct and indirect economic impacts for three stages of the distribution or value chain for Bristol Bay salmon in the United States:

» Fishing and primary processing in Bristol Bay

» Shipping to other states and secondary processing

» Distribution and retailing (nationwide transportation, wholesaling and retailing of Bristol Bay salmon products in stores and restaurants throughout the United States)[1]

[1] The economic effects of distribution and retailing of Bristol Bay salmon are technically economic contributions rather than economic impacts, because if Bristol Bay salmon did not exist stores would sell other products instead, which would still create jobs, income and output value. Because no data are available for Bristol Bay salmon retail volumes and prices, our estimates of economic contributions for this stage are based on the simple assumption that distribution and retailing increases the value of Bristol Bay salmon products by an average of 50%.

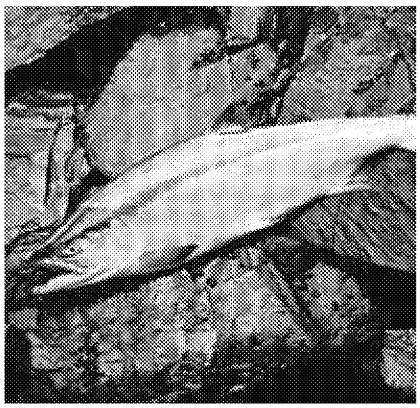
We estimated economic impacts for the United States as well as for Alaska, Washington, Oregon and California in 2010. To estimate economic impacts, we used IMPLAN input-output modeling software which tracks the ripple effects of payments between industries at both the national level as well as within individual states.

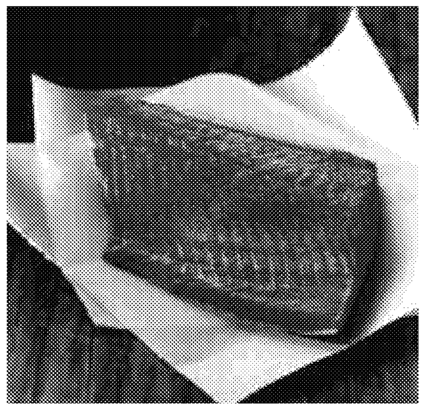
Our economic impact estimates do not account for the fact that Bristol Bay salmon fishing and processing helps to cover a significant share of the fixed costs of many Alaska and Pacific Northwest fishermen and processors, or for the economic benefits of Bristol Bay salmon exports in helping to offset the large United States seafood trade deficit. Thus our estimates of the economic importance of the Bristol Bay seafood industry are conservative.

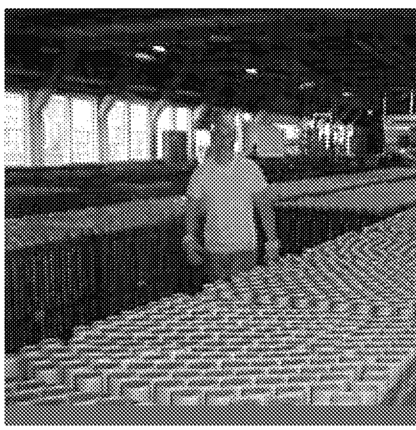
In 2010, almost 12,000 people worked in the Bristol Bay salmon industry during the fishing season, which occurs primarily in June and July. Of these, about 4,400 were Alaska residents, while most of the others were residents of West Coast states.

To compare Bristol Bay seasonal jobs lasting about two months with other year-round employment impacts, we converted them to annual average employment by dividing seasonal employment by six. Expressed as annual average employment, in 2010, almost 10,000 American jobs were created in harvesting, processing, and retailing Bristol Bay salmon and through the multiplier effects of these activities.

In 2010, Americans earned $500 million from harvesting, processing, and retailing Bristol Bay salmon and the multiplier effects of these activities.

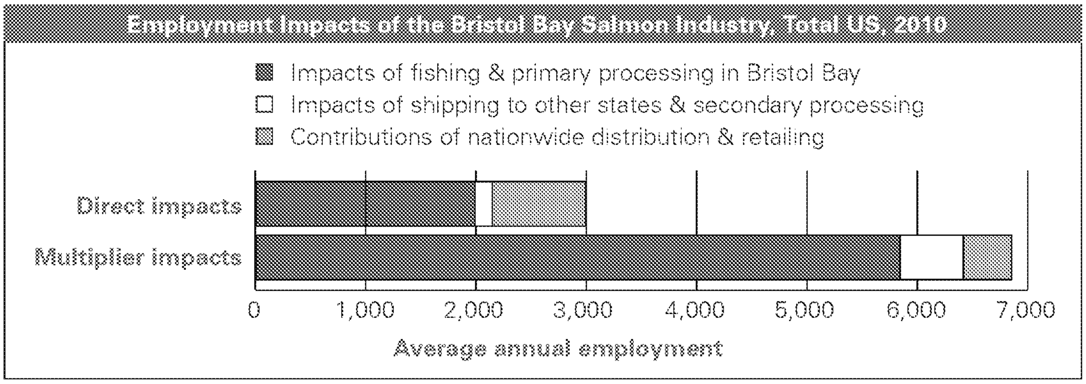


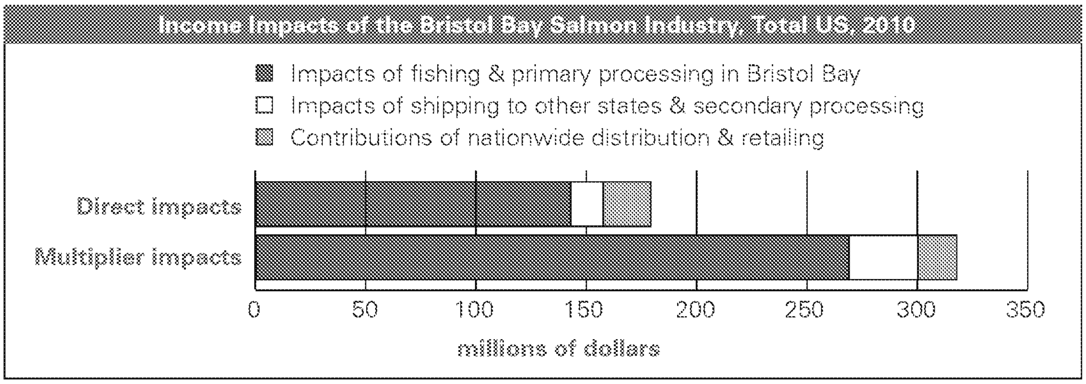


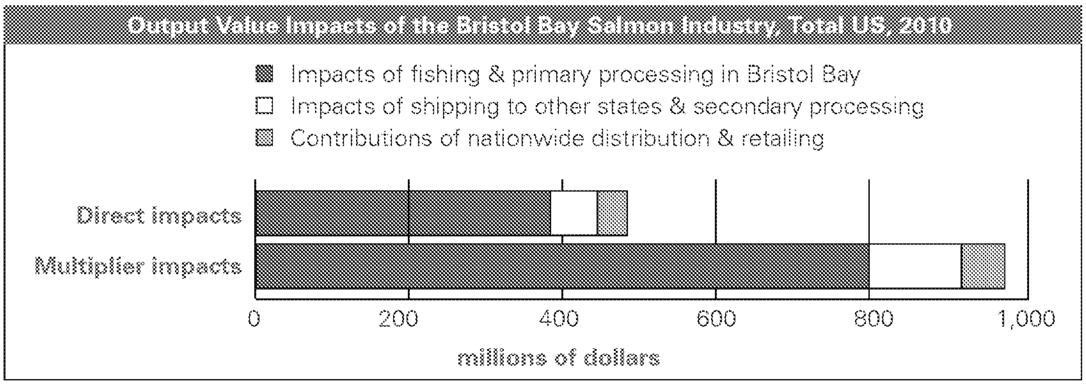


Seasonal Jobs in the Bristol Bay Salmon Industry, by State of Residence, 2010

	Total US	Alaska	Washington	Oregon	California	Other States
Fishing	7,035	3,734	1,948	362	345	646
Processing	4,886	635	1,279	1,781	208	983
Total	11,921	4,369	3,227	2,143	553	1,629







In 2010, $1.5 billion in output value was created in the United States in harvesting, processing, and retailing Bristol Bay salmon and the multiplier effects of these activities.

The tables below provide additional details of our economic impact estimates. A large share of the impacts occur in West Coast states—reflecting the fact that about one-third of Bristol Bay fishermen and two-thirds of Bristol Bay processing workers live in West Coast states; almost all major Bristol Bay processing companies are based in Seattle; most of the supplies and services used in fishing and processing are purchased from Washington; and significant secondary processing of Bristol Bay salmon products occurs in Washington and Oregon.

Employment Impacts of the Bristol Bay Salmon Industry, 2010 (annual average employment)

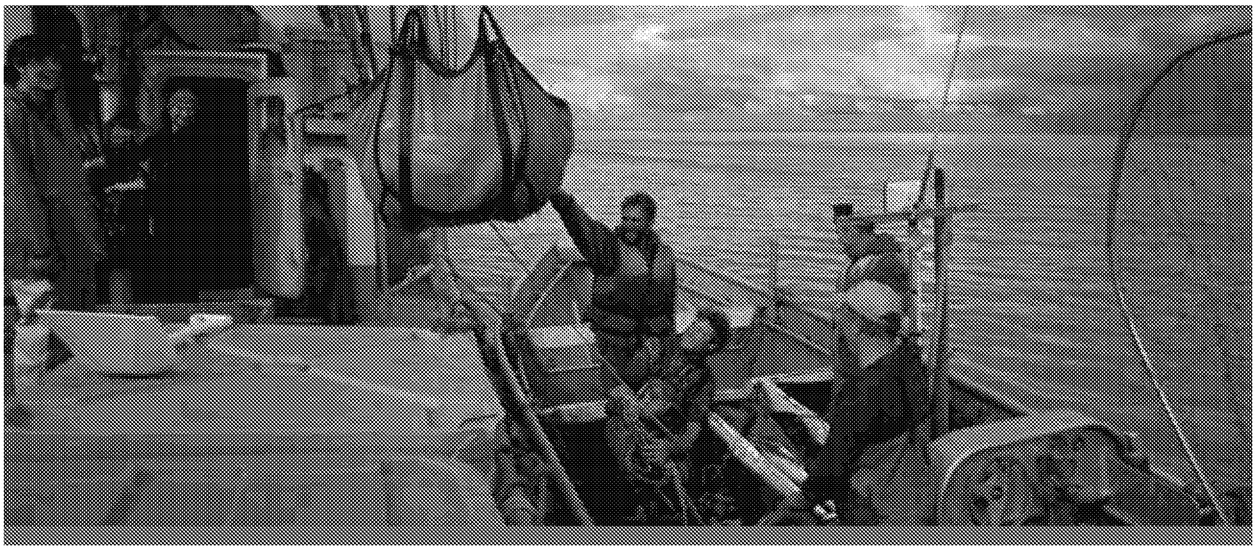
Impact Driver		Total US	AK	WA	OR	CA	Other States
Fishing and primary processing in Bristol Bay	Direct impacts*	1,987	728	538	92	357	271
	Multiplier impacts	5,852	1,338	2,237	163	249	1,865
	Total impacts	**7,839**	**2,066**	**2,775**	**255**	**606**	**2,137**
Shipping to other states and secondary processing	Direct impacts	191		156	15		
	Multiplier impacts	563		229	24		
	Total impacts	**754**		**385**	**39**		
Total impacts		**8,592**		**3,160**	**294**		
Nationwide distribution and retailing**	Direct contributions	787	Note: Total US may exceed sum of estimates shown for individual states; see report for technical explanation. *Direct employment impacts of fishing and processing in Bristol Bay were calculated by dividing seasonal employment by 6. **Based on conservative assumption that distribution and retailing increases value by 50%.				
	Multiplier contributions	425					
	Total contributions	**1,212**					
Total impacts & contributions		**9,804**					

Income Impacts of the Bristol Bay Salmon Industry, 2010 (millions of dollars)

Impact Driver		Total US	AK	WA	OR	CA	Other States
Fishing and primary processing in Bristol Bay	Direct impacts	144	50	48	8	19	18
	Multiplier impacts	268	62	98	7	12	90
	Total impacts	**412**	**112**	**146**	**15**	**31**	**108**
Shipping to other states and secondary processing	Direct impacts	13		11	1		
	Multiplier impacts	30		12	1		
	Total impacts	**43**		**23**	**2**		
Total impacts		**455**		**169**	**17**		
Nationwide distribution and retailing*	Direct contributions	23	Note: Total US may exceed sum of estimates shown for individual states; see report for technical explanation. *Based on conservative assumption that distribution and retailing increases value by 50%.				
	Multiplier contributions	20					
	Total contributions	**42**					
Total impacts & contributions		**497**					

Output Value Impacts of the Bristol Bay Salmon Industry, 2010 (millions of dollars)							
Impact Driver		Total US	AK	WA	OR	CA	Other States
Fishing and primary processing in Bristol Bay	Direct impacts	390	127	198	13	19	32
	Multiplier impacts	801	161	288	19	37	297
	Total impacts	**1,191**	**288**	**486**	**32**	**56**	**329**
Shipping to other states and secondary processing in WA & OR	Direct impacts	68		56	4		
	Multiplier impacts	111		37	3		
	Total impacts	**179**		**93**	**6**		
Total impacts		**1,370**		**580**	**38**		
Nationwide distribution and retailing*	Direct contributions	46					
	Multiplier contributions	61					
	Total contributions	**106**					
Total impacts & contributions		**1,476**					

Note: Total US may exceed sum of estimates shown for individual states; see report for technical explanation. Output value allocated among states based on the residency of fishing and processing workers and business locations.
* Based on conservative assumption that distribution and retailing increases value by 50%.



Conclusions

The Bristol Bay salmon fishery is the world's most valuable wild salmon fishery. It contributes well over $1 billion in value and about 10,000 jobs to the United States economy every year, across multiple industries and states. It has operated continuously for more than 120 years and can continue to provide significant and widespread economic benefits across multiple industries and states for the foreseeable future.

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I. INTRODUCTION

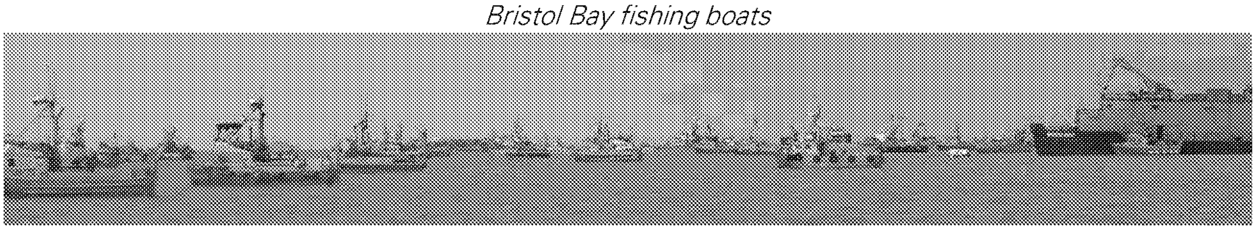
Alaska's Bristol Bay salmon fishery is the world's most valuable salmon fishery. The 2010 Bristol Bay salmon harvest had a value of $165 million. Processing increased the value by $225 million to a total first wholesale value of $390 million for the salmon products produced in Bristol Bay. The Bristol Bay salmon industry employed about 7,000 fishermen and about 4,900 processing workers during the intense June and July fishing season.

This study describes and quantifies the economic importance of the Bristol Bay salmon industry for the United States and for the four west coast states—Alaska, Washington, Oregon and California—which are home to most of the fishermen and processing workers as well as most of the processing companies and the businesses which supply the industry. We estimate "economic impact" measures of the annual average employment, income, and output value (sales value) which the Bristol Bay salmon industry created in 2010 in the United States and in these four states.

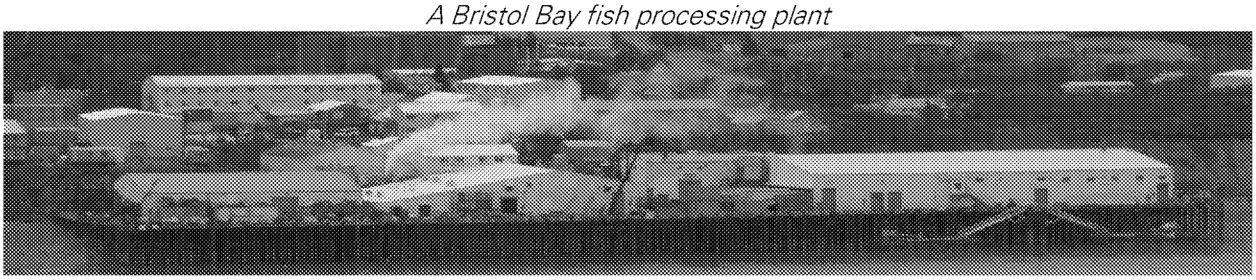
Chapter II of this report provides an overview of the Bristol Bay salmon industry. Chapter III describes our methodology for estimating economic impacts. Chapter IV discusses the *direct economic impacts* of Bristol Bay salmon fishing and processing: the employment, income and output value created in Bristol Bay in fishing and processing. Chapter V discusses the *multiplier economic impacts* of Bristol Bay salmon fishing and processing: the jobs, income and output value created in other industries through the ripple effects of Bristol Bay fishing and processing on the rest of the economy. Chapter VI discusses the *downstream economic effects* of the Bristol Bay salmon industry: the jobs, income and output value created in transportation, secondary processing, warehousing, distribution and retailing after salmon products leave Bristol Bay. Chapter VII summarizes major conclusions of the report.

Estimating economic impacts of the Bristol Bay salmon industry is a technically complex task which required developing numerous assumptions about the payments made by fishermen and processors and in downstream industries as inputs to national and state-level IMPLAN input-output models. To make the report accessible to non-technical readers, in the body of the report we focus on describing our findings. The appendixes provide full technical documentation of our analysis.

Bristol Bay fishing boats

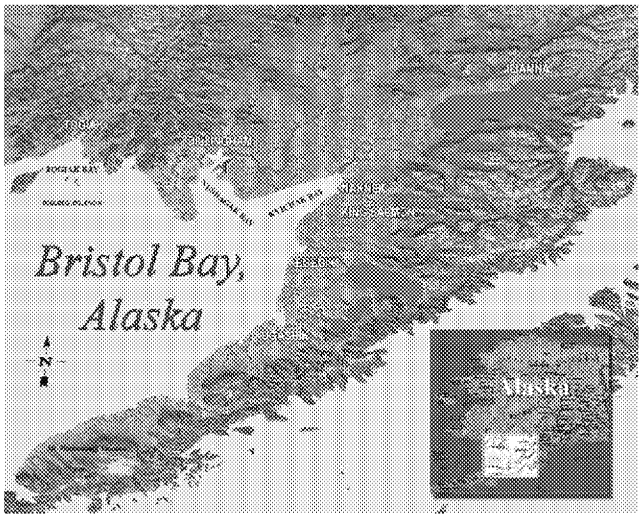


A Bristol Bay fish processing plant



II. OVERVIEW OF THE BRISTOL BAY SALMON INDUSTRY

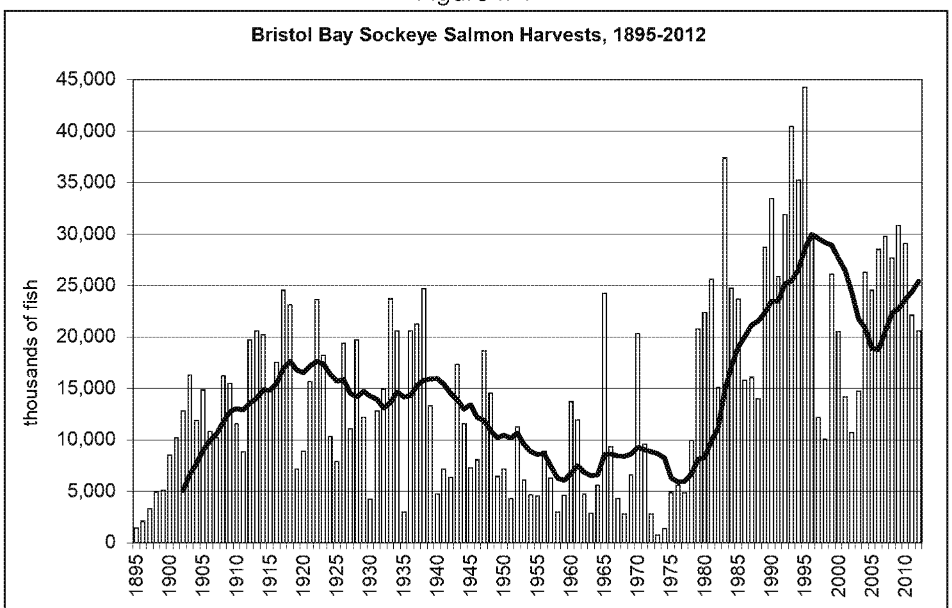
Bristol Bay is located in southwestern Alaska. Each year tens of millions of sockeye salmon return to spawn in the major river systems which flow into Bristol Bay. The large lakes of the Bristol Bay region provide habitat for juvenile sockeye salmon during their first year of life.



Source: Environmental Protection Agency

For well over a century, Bristol Bay salmon have supported a major salmon fishing and processing industry. During the 118 years between 1895 and 2012, Bristol Bay fishermen harvested more than 1.7 billion sockeye salmon, with an annual average harvest of 15 million sockeye salmon. Harvests have been particularly strong since 1980, with an annual average harvest of 24.6 million sockeye salmon during the period 1980-2012.

Figure II-1



Source: ADFG. Note: the black line shows the average annual catch for the preceding 10 years.

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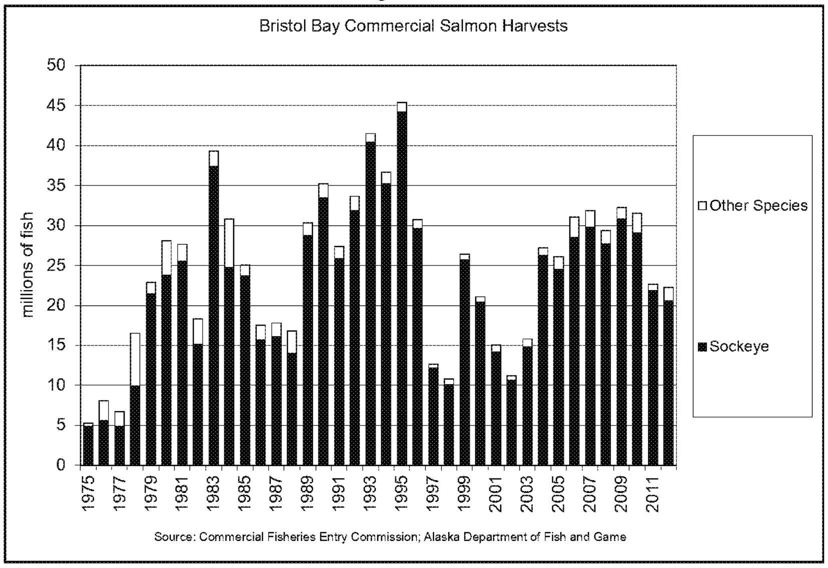
Bristol Bay commercial salmon harvests are overwhelmingly sockeye salmon, although the other four species of Pacific salmon are also caught in Bristol Bay in much smaller numbers. Except where otherwise noted, references in this report to Bristol Bay salmon are specifically for Bristol Bay *sockeye* salmon.

Figure II-2



Bristol Bay salmon runs vary widely from year to year and over longer periods of time, due to variations in the freshwater and marine environments which affect salmon survival rates over their life-cycle. The Alaska Department of Fish and Game (ADF&G) manages the fishery to achieve "escapement" goals for the number of fish which "escape" the commercial fishery and enter the different Bristol Bay river systems to spawn, by opening and closing fishing in different districts multiple times over the season.

Bristol Bay fishermen fished from sailboats until the 1950s

Source: "Sailing for Salmon" exhibition of historic Bristol Bay photographs at Anchorage Museum, summer 2011 (http://www.anchoragemuseum.org)

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Most of the Bristol Bay salmon harvest occurs between mid-June and mid-July. In early July, at the peak of the fishing season, millions of salmon may be harvested in a single day. During this time, Bristol Bay is a frenzy of activity, with many thousands of fishermen and fish processors working around the clock.

Bristol Bay Fishing

Bristol Bay salmon are harvested using gillnets. Gillnets hang in the water perpendicular to the direction in which returning salmon are swimming. The fish get their heads stuck in the nets and are "picked" from the net as it is pulled from the water.

There are two types of gillnet fishing operations in Bristol Bay: drift gillnet and set gillnet. Drift gillnet fishing is done from fishing boats, which are limited to 32 feet in length. Fishermen let the net out behind the boat, and after a period of time pull it back into the boat to pick the fish. In set gillnet fishing, one end of the net is attached to the shore, while the other is attached to an anchor in the water. Fishermen pick the fish from a skiff or from the beach at low tide.

Picking salmon on a Bristol Bay drift gillnet boat

A set-net fishing operation

Like all Alaska salmon fisheries, the Bristol Bay salmon fishery is managed under the state of Alaska's limited entry management system. Only holders of "limited entry permits" and their crew are allowed to fish in Bristol Bay. There are approximately 1,860 drift gillnet permits and approximately 1,000 set net permits. Average drift gillnet catches are higher than average set gillnet catches, and drift gillnet fishermen catch about four-fifths of the Bristol Bay sockeye salmon harvest.

When the limited entry system was implemented in the 1970s, permits were allocated for free to fishermen with a history of participation in the fishery. Since then, fishermen have gotten permits only by gift, inheritance or (most commonly) buying them from other fishermen. Permit prices vary with economic conditions in the fishery. In 2010, the average price of a drift net permit was about $102 thousand and the average price of a set net permit was about $29 thousand.

Bristol Bay permit holders fish with an average of about two crew members (larger operations have more crew members), so the total number of Bristol Bay fishermen is approximately three times the number of permit holders. Crew are paid a share of the catch value after deducting food and fuel costs (typically about 10%). Permit holders net earnings depend on the value of their catch minus crew shares and a variety of other operating costs (the largest of which include food, fuel, nets, maintenance, and transportation) and capital costs (payments for boats and permits).

In 2010, Alaska residents owned 53% of Bristol Bay permits but caught only 42% of the fish. This is because Alaskans owned a smaller share of the drift gillnet permits, and had lower average catches in the drift gillnet fishery. The fact that well over half of the value of Bristol Bay catches goes to residents of other states is a major reason why a large share of the economic impacts of the fishery occur in other states.

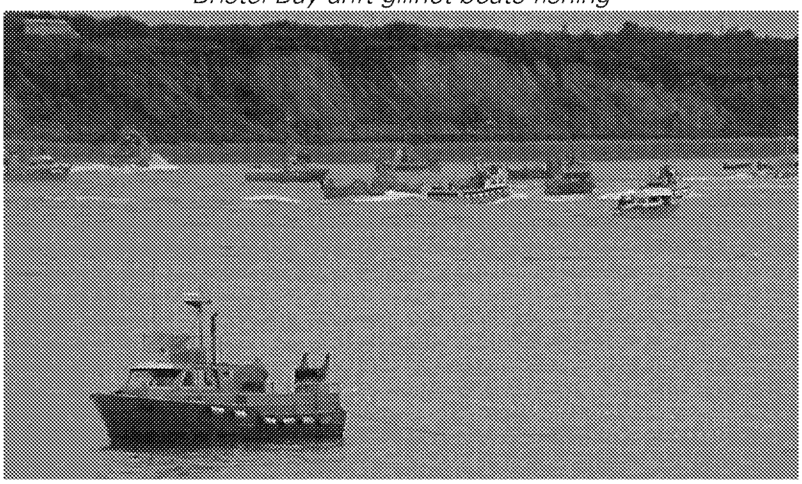
Table II-1

Bristol Bay Limited Entry Permit Holders, Catches and Gross Earnings, by State, 2010

	Fishery	Total	Alaska	Washington	Oregon	California	Other
Number of permit holders	Drift	1,850	845	642	98	109	156
	Set	927	629	127	38	34	99
	Total	2,777	1,474	769	136	143	255
	% of total	100%	53%	28%	5%	5%	9%
Number of permits fished	Drift	1,494	650	538	87	87	138
	Set	861	566	124	40	35	100
	Total	2,355	1,216	662	127	122	238
	% of total	100%	52%	28%	5%	5%	10%
Average catch per permit fished (lbs)	Drift	98,542	84,562	112,538	103,907	99,132	101,788
	Set	39,495	38,077	36,323	44,486	44,233	46,215
	Total	76,954	62,925	98,262	85,192	83,382	78,438
Total catch (million lbs)	Drift	147.2	55.0	60.5	9.0	8.6	14.0
	Set	34.0	21.6	4.5	1.8	1.5	4.6
	Total	181.2	76.5	65.0	10.8	10.2	18.7
	% of total	100%	42%	36%	6%	6%	10%
Total gross earnings ($ millions)	Drift	134.1	49.5	55.3	8.4	8.1	12.9
	Set	31.0	19.5	4.2	1.6	1.4	4.2
	Total	165.2	69.0	59.5	10.0	9.5	17.1
	% of total	100%	42%	36%	6%	6%	10%

Source: CFEC Permit and Fishing Activity Data.

Bristol Bay drift gillnet boats fishing



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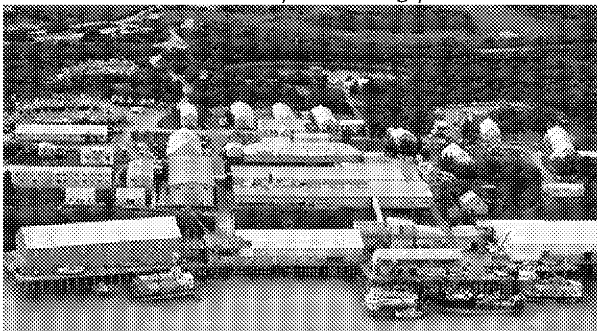
Bristol Bay Salmon Processing

Fish processing is an integral part of the Bristol Bay salmon industry, employing approximately half as many people as fish harvesting and more than doubling the value of the fish. Bristol Bay salmon are processed by about 10 large processing companies (most of which have multiple processing facilities) and 20 smaller companies employing about 5,000 processing workers at the peak of the season. Almost 90% of the processing workers are from other states and live in bunkhouse facilities at the processing plants.

Bristol Bay salmon are processed in both land-based processing facilities and on floating processors. Salmon are canned only in large land-based facilities, which also have salmon freezing capacity. Floating processors produce only frozen salmon.

A land-based processing plant



A floating processor

In 2010, six companies operated salmon canning facilities in Bristol Bay. These included some of the largest seafood processing companies operating in Alaska. Most of these companies have both land-based and floating processing operations in many parts of Alaska, which process not only salmon but other major Alaska species as well, such as pollock, crab and halibut. The home offices of all of the large Bristol Bay processors are in or near Seattle.

Table II-2

Large Bristol Bay Salmon Processors and Buyers, 2010

Type of processor	Company	Home Office Location	Types of processing capacity				Shipping*	
			Canned	Frozen	Fresh	Cured	Air	Sea
Major processors with both canning and freezing capacity	Peter Pan Seafoods, Inc.	Seattle, WA	X	X	X	X	X	X
	Icicle Seafoods, Inc.	Seattle, WA	X	X	X		X	X
	Ocean Beauty Seafoods, Inc.	Seattle, WA	X	X	X		X	X
	Trident Seafoods	Seattle, WA	X	X	X		X	X
	Yard Arm Knot Fisheries, LLC	Seattle, WA	X	X				X
	Alaska General Seafoods	Kenmore, WA	X	X	X		X	
Other large processors	Leader Creek Fisheries, LLC	Seattle, WA		X				X
	Snopac Products, Inc.	Seattle, WA		X	X		X	X
	Pederson Point	Seattle, WA		X				X
	Togiak Fisheries	Seattle, WA		X				X
	Ekuk Fisheries	Seattle, WA		X	X		X	X

Note: Other Bristol Bay processors in 2010 included seven buyers with both frozen and fresh capacity; nine buyers with only frozen capacity, and eight buyers with only fresh or cured capacity.

*How processors/buyers shipped products from Bristol Bay

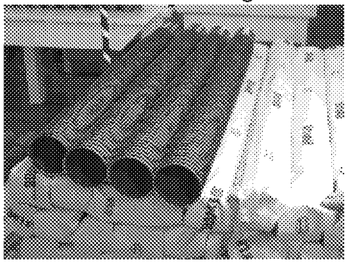
Source: Alaska Department of Fish and Game, Bristol Bay Annual Management Report 2010, Table 25.

A processing worker holding a sockeye salmon

Workers cleaning salmon

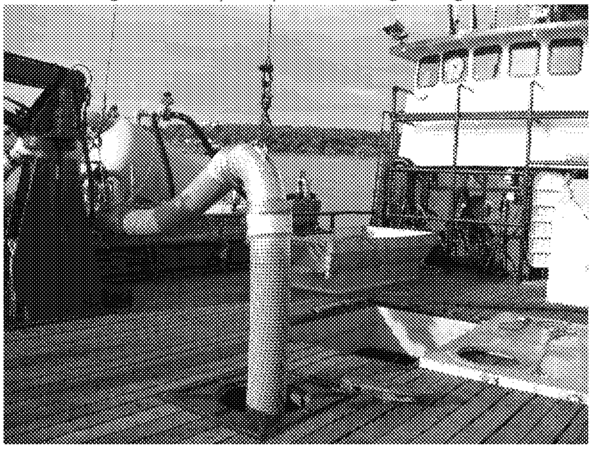
Fish account for the largest share of costs of Bristol Bay processors. Other important costs include labor, fish tendering, packaging (boxes and cans), transportation of products and workers, utilities, maintenance, and capital costs of equipment and buildings. Processing costs per pound vary between product forms and from year to year as fixed costs are spread over different volumes of salmon.

Processing costs: salmon cans (stacked in tubes), boxes, processing machinery



Most larger Bristol Bay salmon processors contract with tender vessels to transport salmon from fishing vessels at or near the best fishing areas to land-based or floating processing facilities. Tendering represents a significant cost for the industry.

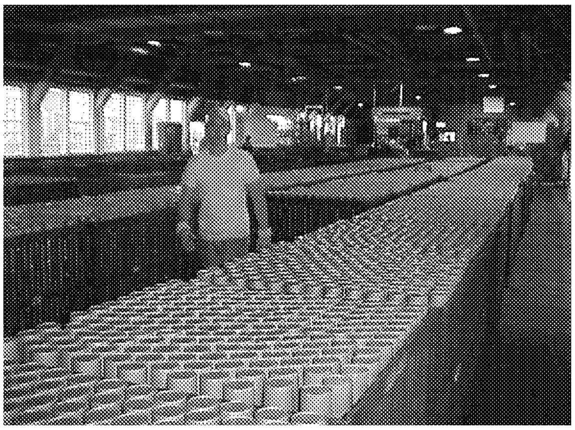
Fish are transferred from fishing boats to tenders in brailer bags or are pumped through large hoses.



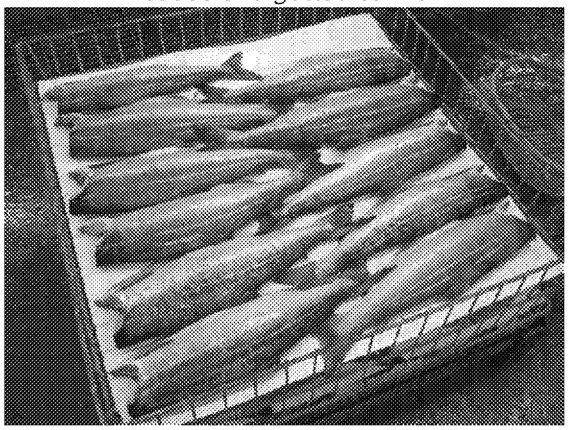
Bristol Bay Salmon Products

Bristol Bay salmon are processed into four major *primary products*: frozen salmon, canned salmon, fresh salmon, and salmon roe. Frozen salmon includes both headed and gutted (H&G) salmon as well as salmon fillets.

Canned salmon



Headed and gutted salmon



Bristol Bay sockeye salmon fillet

Processing Bristol Bay sockeye salmon roe

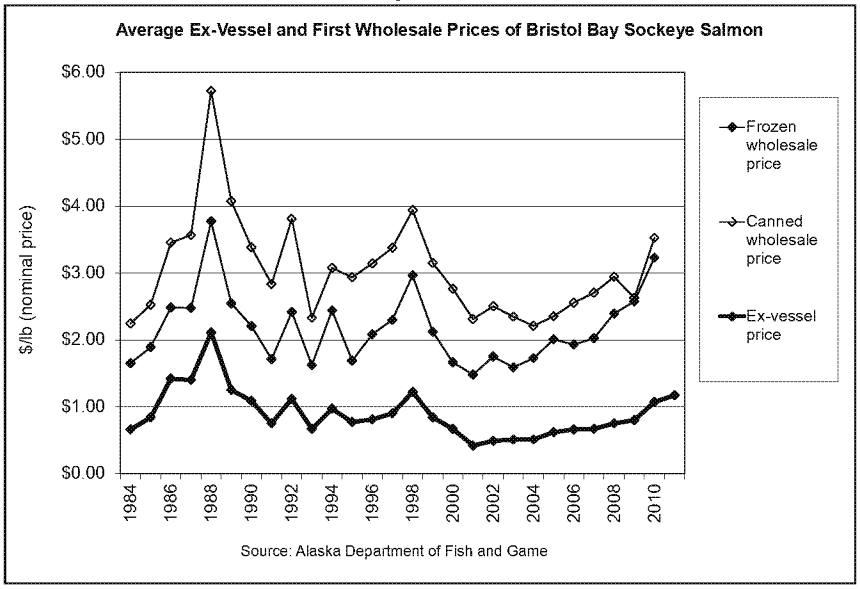
In 2010, frozen salmon accounted for 69% of Bristol Bay production volume, followed by canned salmon (26%), salmon roe (3%) and fresh salmon (2%). The shares of different product forms in Bristol Bay production vary from year to year, reflecting variations in harvests as well as variations in the relative prices of different products.

Bristol Bay Salmon Prices and Value

Two kinds of prices and values matter for the Bristol Bay salmon industry. *Ex-vessel prices* are the prices processors pay fishermen for their fish. The *ex-vessel value* is the ex-vessel price times the harvest volume, or fishermen's gross earnings. *First wholesale prices* are the prices customers (typically large retail chains, wholesalers, and importers in other countries) pay processors for the frozen, canned, fresh and other products they produce. The *first wholesale value* is the sum of the different wholesale prices times the product volumes sold, or processors' gross earnings.

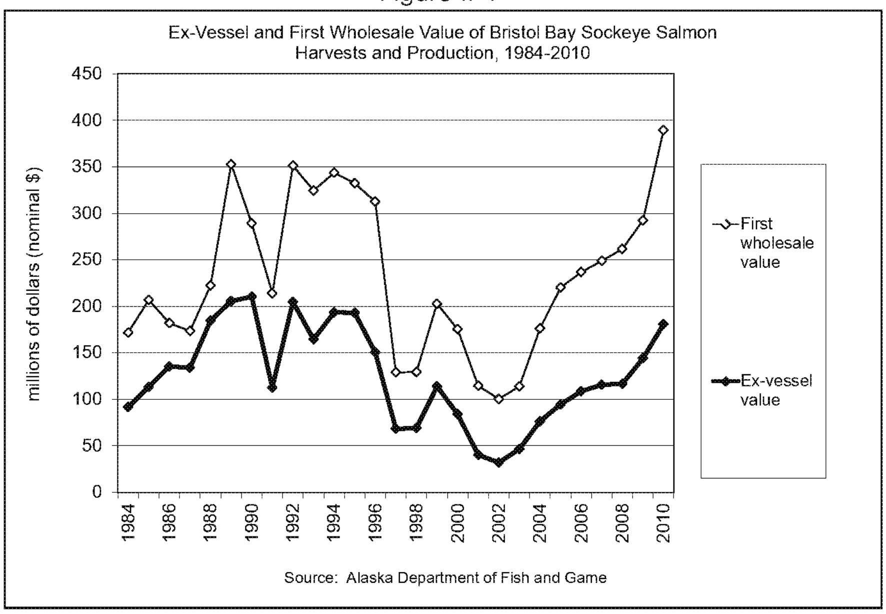
Bristol Bay salmon prices and value can vary widely from year to year and over longer periods of time, reflecting changes in salmon market conditions and in harvests. Prices rose dramatically during the 1980s because of strong Japanese market demand. From the late 1980s to the early 2000s prices fell dramatically. The main cause of the decline was competition from rapidly growing production of farmed salmon. Other factors included a slowdown in the Japanese economy and competition from Russian and Japanese wild salmon—as well as large Alaska harvests.

Figure II-3



Source: Alaska Department of Fish and Game

Figure II-4[1]



Source: Alaska Department of Fish and Game

[1] ADF&G and CFEC report different ex-vessel values for Bristol Bay salmon in 2010. Our economic impact analysis is based on CFEC data. The data in this figure and in Table II-3 below are based on ADF&G data. For discussion, see Appendix A, Ex-Vessel Value of Bristol Bay Salmon Harvests.

Since 2002, Bristol Bay salmon prices have rebounded dramatically, due to growing world salmon demand, development of new product forms such as salmon fillets and portions, improved fish handling and quality, diversification of markets, and sustained and effective marketing by Alaska processors and the Alaska Salmon Marketing Institute. These favorable market trends are likely to continue, although global economic conditions and global salmon supply will continue to affect market conditions, leading to lower prices in some years (as occurred in 2012).

Both prices and catches affect the ex-vessel and first-wholesale value of Bristol Bay salmon. Both lower prices and lower catches contributed to the decline in value during the 1990s. Both higher prices and higher catches contributed to the recovery in value since 2002. (Data for 2011 and 2011 were not yet available, but first wholesale value likely fell due to lower catches in both years, and lower prices in 2012).

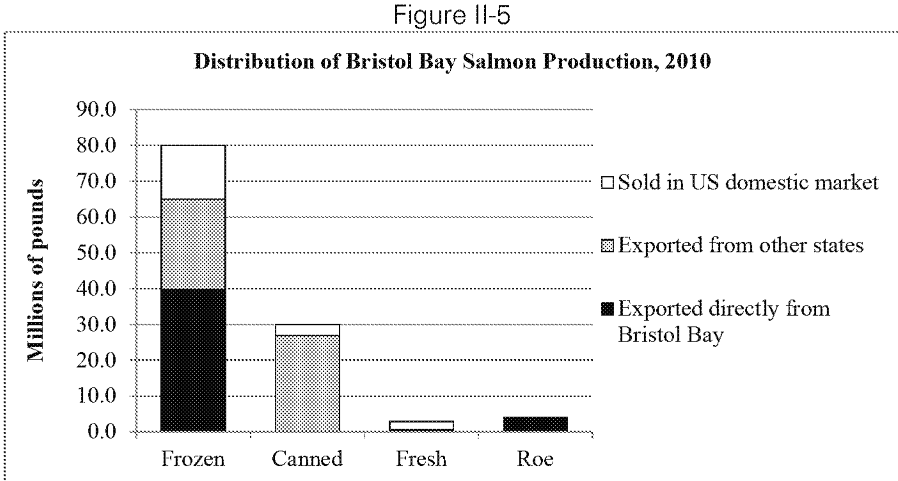
Bristol Bay Salmon End Markets

End markets for Bristol Bay salmon vary widely for different product forms. Prior to the mid-1990s, almost all Bristol Bay *frozen salmon* was shipped to Japan, and the industry was very dependent on Japanese salmon market conditions. Since then the Japanese market share has declined dramatically. Major markets for Bristol Bay frozen salmon now include not only Japan but also the United States, the European Union, and China (where frozen salmon is reprocessed into value-added products and re-exported to global markets).

Currently about half of Bristol Bay frozen salmon is exported directly from Bristol Bay, primarily to Japan and China. Most of the remaining frozen salmon is shipped to Washington where much of it is repackaged and/or reprocessed into secondary products such as fillets, portions and smoked salmon. Some of these products are exported while the rest are sold in the US domestic market.

Bristol Bay *canned salmon* is shipped to warehouses in Washington and Oregon where it is stored, labeled, and sold by processors over the course of the year, mostly to the United Kingdom and other export markets. Small volumes of *fresh salmon* are shipped by air to the Lower 48 states and Canada. Almost all sockeye salmon *roe* is exported, mostly to Japan and Russia.

Figure II-5



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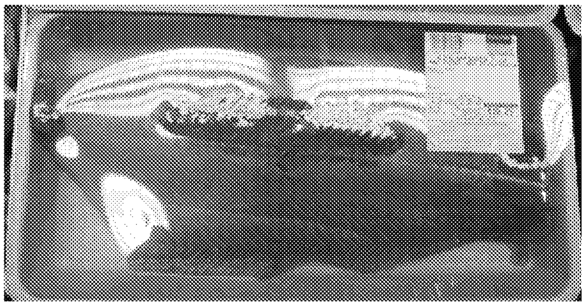
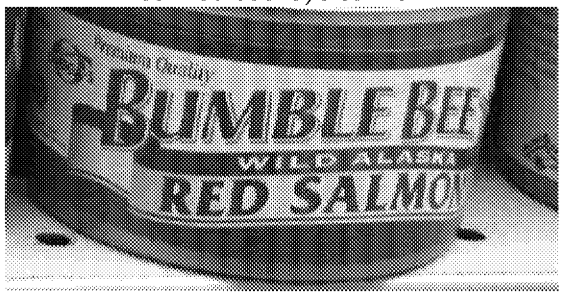
Major US sockeye salmon retail products

Salmon fillet



Canned sockeye salmon



Containers for shipping Bristol Bay salmon products at the Bristol Bay port of Naknek

Bristol Bay Salmon Support Industries

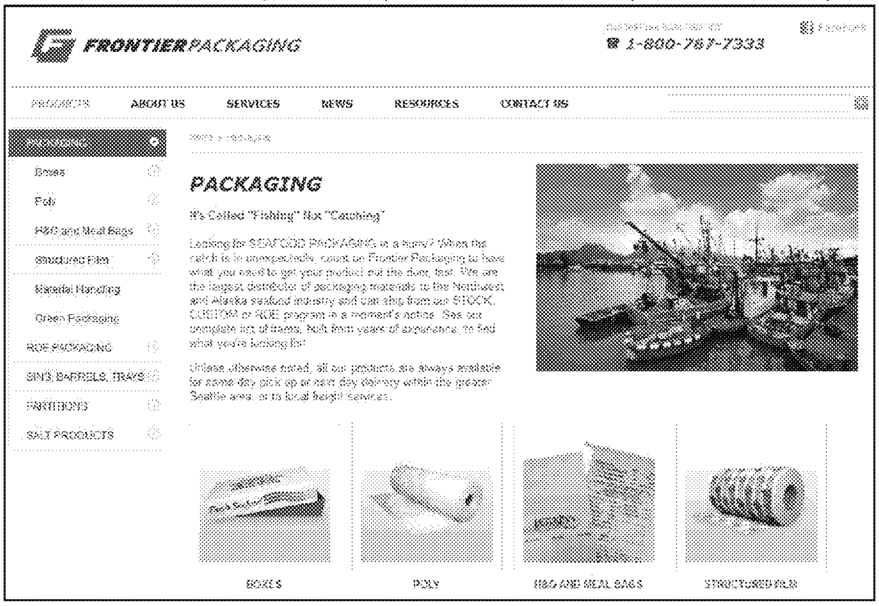
The Bristol Bay salmon industry is much more than fishing and processing. A wide range of industries provide supplies and services to the industry. Some of these, such as those pictured above and below, are based in Bristol Bay. Most are based in other states—particularly Washington—such as marine transportation companies, boat builders, machinery and electronics suppliers, packaging manufacturers, banks and insurance companies. As a Bristol Bay processor told us, "Bristol Bay banks in Seattle." More generally, Bristol Bay *shops* in Seattle—which is another reason why a large share of the economic impacts of the Bristol Bay salmon industry occur in Washington.

Net hanging & mending

Boat storage and repair

Air freight

Located in Washington—but part of the Bristol Bay salmon industry



Relative Scale of Bristol Bay Salmon Industry

The Bristol Bay salmon fishery is a world-scale commercial salmon fishery. Between 2005 and 2010, Bristol Bay averaged 67% of total Alaska sockeye salmon harvests (by volume), 50% of world sockeye salmon harvests, 21% of all Alaska wild salmon harvests, and 8% of all world wild salmon harvests. It accounted for 31% of the ex-vessel value of all Alaska wild salmon harvests, 13% of the ex-vessel value of all world wild salmon harvests, and 3% of the value of all United States fish and shellfish harvests. In 2010, the ex-vessel value of Bristol Bay salmon harvests exceeded the total ex-vessel value of fish harvests in all but nine states (not counting Alaska).

These numbers are inadequate to convey the scale of the Bristol Bay salmon industry. It is difficult to appreciate the scale of the industry without seeing it in person—thousands of fishing boats spread out across vast fishing districts, hundreds of other vessels ranging from tenders to floating processors and ocean freighters, and dozens of processing operations with thousands of workers processing tens of millions of fish.

Table II-3

Selected Indicators of the Relative Scale of the Bristol Bay Salmon Industry

Measure		2005	2006	2007	2008	2009	2010	Average
Bristol Bay sockeye salmon harvest volume as a share of:	Alaska sockeye salmon	58%	69%	62%	71%	71%	70%	67%
	World sockeye salmon	47%	49%	47%	52%	55%		50%
	Alaska wild salmon (all species)	16%	22%	18%	23%	25%	21%	21%
	World wild salmon (all species)	7%	8%	7%	9%	7%		8%
Bristol Bay sockeye salmon ex-vessel value as a share of:	Alaska wild salmon ex-vessel value (all species)	30%	32%	28%	27%	36%	31%	31%
	World wild salmon ex-vessel value (all species) *	15%	15%	14%	12%	11%		13%
	United States fish & shellfish landed value (all species)	2%	3%	3%	3%	4%	4%	3%

* Valued at average prices of Alaska wild salmon, by species.

Note: Complete world wild salmon supply data not available for 2010.

Sources: Alaska data: ADFG Alaska Commercial Salmon Harvests and Ex-vessel Values Reports and CFEC Basic Information Tables data. Other wild salmon supply data: FAO FishstatJ database (Canada, Japan, Russia), National Marine Fisheries Service (US Pacific Northwest data).

Table II-4

Ex-Vessel Value of Total Fishery Landings for Selected States Compared with the Ex-Vessel Value of Bristol Bay Salmon Harvests, 2010

State	Ex-vessel value (millions of dollars)	Ratio of total state ex-vessel value to Bristol Bay ex-vessel value	Ratio of Bristol Bay ex-vessel value to total state ex-vessel value
Alaska	1584.0	9.59	0.10
Massachusetts	478.5	2.90	0.35
Maine	375.1	2.27	0.44
Washington	272.3	1.65	0.61
Louisiana	247.9	1.50	0.67
Texas	204.1	1.24	0.81
Virginia	198.8	1.20	0.83
California	189.3	1.15	0.87
Florida	184.4	1.12	0.90
New Jersey	177.9	1.08	0.93
Bristol Bay salmon	165.2	1.00	1.00
Oregon	104.6	0.63	1.58
Maryland	95.9	0.58	1.72
Hawaii	84.0	0.51	1.97
North Carolina	79.9	0.48	2.07
Rhode Island	62.6	0.38	2.64
All other states	180.0	1.09	0.92
Total, all states	4519.5	27.36	0.04

Source: National Marine Fisheries Service, *Fisheries of the United States, 2010.*

Data sources for this chapter

Historical salmon catches (1878-1997) are from Byerly et al (1999). Other salmon harvest data are from ADFG Alaska Commercial Salmon Harvests and Ex-vessel Values Reports. Numbers of permits and average 2010 permit prices are from CFEC Basic Information Tables. Ex-vessel prices are from ADFG Salmon Ex-Vessel Price Time Series by Species 1984-2008. Ex-vessel value is from ADFG Alaska Commercial Salmon Harvests and Ex-vessel Values Reports. First wholesale prices and value are from ADFG COAR data. World salmon harvest data used to calculate shares of world harvests are from FAO FishstatJ database and NMFS Commercial Fishery Landings database. For details of these data sources, refer to Appendix F.

III. OVERVIEW OF STUDY METHODOLOGY

The *economic impacts* of an industry are the jobs, income and output value (sales) created by the industry—or the jobs, income and output value that would not exist if the industry did not exist. For this study, we estimated economic impacts of the Bristol Bay salmon industry for the United States nationally and for the four west-coast states of Alaska, Washington, Oregon and California. This chapter provides an overview of our methodology for estimating economic impacts.

Types of Economic Impacts

Economic impacts may be divided into *direct economic impacts* and *multiplier economic impacts.*

- *Direct economic impacts* of the Bristol Bay salmon industry are the jobs, income and output value created in those businesses directly involved in fishing for, processing, distributing and retailing Bristol Bay salmon.

- *Multiplier economic impacts* are the jobs, income and output value created in other industries.

Multiplier economic impacts include both indirect impacts and induced impacts. *Indirect economic impacts* are the jobs, income and output value created by the ripple effects of business purchases. *Induced economic impacts* are the jobs, income and output value created by the ripple effects of household purchases.

When Bristol Bay fishermen buy nets, they create indirect impacts in the net manufacturing industry. When Bristol Bay fishermen get haircuts, they create induced impacts in the hair-cutting industry.

Distribution Chain Stages for Which We Estimated Economic Impacts

We estimated direct and multiplier economic impacts for three stages of the distribution chain for Bristol Bay salmon in the United States:

- *Fishing and primary processing in Bristol Bay*

- *Shipping and secondary processing.* This included:

    - Marine transportation of frozen salmon to Washington state
    - Secondary processing of Bristol Bay frozen salmon in Washington State.
    - Marine transportation of canned salmon to Washington and Oregon
    - Warehousing and labeling of canned salmon in Washington and Oregon

- *Distribution and retailing.* This included nationwide transportation, wholesaling and retailing of Bristol Bay salmon products in stores and restaurants throughout the United States, including frozen salmon, canned salmon and fresh salmon. Technically, as discussed below, the economic effects of distribution and retailing are economic *contributions* rather than economic *impacts.*

We refer to the stages of the distribution chain after Bristol Bay (shipping and secondary processing, and distribution and retailing) as *downstream* stages of the distribution chain, and we refer to their economic impacts as *downstream economic impacts.*

Geographic Regions for Which We Estimated Economic Impacts

As shown in Table III-1, we estimated economic impacts of these three stages of the Bristol Bay salmon distribution chain for different combinations of geographic regions. We estimated economics impacts of fishing and primary processing in Bristol Bay for the United States nationally as well as for the four west coast states of Alaska, Washington, Oregon and California. We estimated economic impacts for "other states" by subtracting estimated economic impacts for the four west coast states from estimated national economic impacts.

We estimated economic impacts of shipping to and secondary processing in Washington and Oregon for the United States as well as for the states of Washington and Oregon. We estimated economic contributions of nationwide distribution and retailing only for the United States as a whole, because we lacked sufficient data to develop estimates of these contributions for individual states.

Table III-1

Types of Economic Impacts and Contributions of the Bristol Bay Salmon Industry Estimated in This Report

Impact driver	Types of Impacts & Activity	United States	Alaska	Washington	Oregon	California	Other states**
Fishing and processing in Bristol Bay	Direct impacts	X	X	X	X	X	X
	Indirect impacts	X	X	X	X	X	X
	Induced impacts	X	X	X	X	X	X
	Multiplier impacts*	X	X	X	X	X	X
	Total impacts	X	X	X	X	X	X
Shipping to and secondary processing in Washington & Oregon	Direct impacts	X		X	X		
	Indirect impacts	X		X	X		
	Induced impacts	X		X	X		
	Multiplier impacts*	X		X	X		
	Total impacts	X		X	X		
Nationwide distribution and retailing	Direct contribution	X					
	Indirect contribution	X					
	Induced contribution	X					
	Multiplier contribution	X					
	Total contribution	X					

* Multiplier impacts are the sum of indirect and induced impacts. **Estimated by subtracting impacts estimated for the four western states from impacts estimated for the US.

Estimation of Economic Impacts for 2010

The economic impacts of the Bristol Bay salmon fishery vary from year to year due to variation in Bristol Bay salmon catches, prices, the mix of products produced, fishery participation, employment and other fishery characteristics. For this report, we estimated economic impacts of the Bristol Bay salmon industry in 2010. We chose 2010 because it was the most recent year for which comprehensive economic data were available at the time we began this study.

In the recent past, Bristol Bay salmon harvests, prices and value—and the economic impacts they drive—have been both higher and lower than they were in 2010. Similarly, in the future, there will likely be years when harvests, prices, value and economic impacts of the Bristol Bay salmon industry will be higher and lower than they were in 2010. The economic impacts of the Bristol Bay salmon industry are *not* equal every year to the impacts we estimated for 2010. However, the economic impacts of the Bristol Bay salmon industry in 2010 *do* provide a reasonable illustration of the overall scale and nature of the economic impacts of the industry and the distribution of those impacts between states.

Methodology for Estimating Economic Impacts

Direct Economic Impacts of Bristol Bay Salmon Fishing and Processing

The direct economic impacts of Bristol Bay salmon fishing and processing are the employment, income and output value created in fishing and processing operations in Bristol Bay. To estimate direct economic impacts, we relied primarily on data and estimates published by several Alaska state agencies, including the Alaska Commercial Fisheries Entry Commission (CFEC), the Alaska Department of Fish and Game (ADF&G), and the Alaska Department of Labor and Workforce Development (ADLWD). Chapter IV describes our estimates of these direct economic impacts, and Appendix A provides technical details of our data, assumptions and analysis.

Multiplier Economic Impacts of Bristol Bay Salmon Fishing and Processing

The multiplier economic impacts of Bristol Bay salmon fishing and processing are the indirect and induced employment, income and output value resulting from the fishing and processing that occurs in Bristol Bay. We followed a three-stage process to estimate multiplier economic impacts.

First, we estimated how the value created by the Bristol Bay salmon industry in 2010 was divided up. In 2010, Bristol Bay salmon processors were paid a total first wholesale value of $390 million for the salmon products they produced in the Bristol Bay fishery. All of this money was paid to someone for something: either for the labor of fishing crew and processing workers, for fishermen's and processors' purchases from other businesses, or as returns to the investments of permit holders and processing company owners in fishing permits, fishing gear and processing plants.

As discussed in Chapter V, we estimated that in 2010 processors paid $165 million to salmon permit holders. Of the remaining $225 million, we estimated that processors paid $34 million for labor, $23 million for packaging, $7 million for insurance, and so on for many other types of payments. Of the $165 million paid to salmon permit holders, we estimated that they paid $37 million to fishing crew, $5 million for transportation, and so on for many other types of payments.

Second, we estimated what states each type of payment went to. For example, we estimated that of the $34 million processors paid for labor, $4 million went to residents of Alaska, $9 million went to residents of Washington, and so forth. We estimated that of the $23 million processors spent for packaging, they spent $14 million in Washington and $9 million in California. We estimated that of the $5 million fishermen spent for transportation, they spent $2 million in Alaska, $2 million in Washington, and $1 million in other states.

Our estimates for these first two steps—estimating how the $390 million in value created by the Bristol Bay salmon industry was divided up, and what states it went to—were based on State of Alaska data for permit holders' and processing workers' earnings, earlier studies of permit holders' costs, discussions with industry sources, and our best judgment.

Third, we used IMPLAN input-output models to estimate the multiplier economic impacts (indirect and induced impacts) resulting from different types of payments to different states to calculate the multiplier economic impacts of Bristol Bay salmon and fishing nationally and in the four west coast states. The input-output models track the ripple effects of payments as money flows through the economy. For example, when salmon processors buy cans for canning salmon, it creates jobs and income in the can manufacturing industry. In turn the can manufacturers buy metal and machines to make the cans, which creates jobs in the metal mining and machine manufacturing industries. Input-output models track and add-up all of these effects to calculate multiplier impacts.

Chapter V describe our estimates of the multiplier economic impacts of Bristol Bay salmon fishing and processing, and Appendix B provides technical details of our data, assumptions and analysis. Appendix D provides technical details of our use of IMPLAN input-output models.

Downstream Economic Impacts

The downstream economic impacts of the Bristol Bay salmon industry are the economic impacts resulting from transporting, processing and retailing Bristol Bay salmon products within the United States after they leave Bristol Bay. We followed a three-stage process to estimate downstream economic impacts.

First, we estimated end-markets for Bristol Bay salmon products. A large share of Bristol Bay salmon is exported. We subtracted estimated exports from total production to estimate how much Bristol Bay salmon is transported within, processed in and sold in the United States. Second, we estimated the increase in value in the "downstream" industries involved in transporting, processing and retailing Bristol Bay salmon products in the United States. Third, we used IMPLAN input-output models to estimate the multiplier economic impacts (indirect and induced impacts) resulting from payments by downstream industries. Chapter VI describe our estimates of downstream economic impacts of Bristol Bay salmon, and Appendix C provides technical details of our data, assumptions and analysis.

In estimating national economic contributions of distribution and retailing, we had no data on the costs associated with distribution and retailing or the prices at which products were sold at retail. It was far beyond the scope of this project to collect this kind of information. For this reason, for our analysis we made the simple and conservative assumption that distribution and retailing increases the value of Bristol Bay salmon products by an average of 50%. Our estimates of the economic contribution of the distribution and retailing of Bristol Bay salmon should be interpreted as estimates of *what the associated jobs, income and output value would have been if the average increase in value were 50%*, rather than as a precise estimate of what they were. It is likely that the actual economic contributions associated with distribution and retailing in 2010 were at least as high as our estimates, and possible that they were significantly higher.

Definitions for Selected Economic Terms Used in this Report

Economic contribution and economic impact. Economists distinguish between two closely related concepts: *economic contribution* and *economic impact*. Economic contribution is the jobs, income and output value associated with an industry. It is sometimes called *economic activity*. Economic impact is the *net* jobs, income and output value associated with an industry—or how total jobs, income and output value in the economy would change if the industry didn't exist.

As a simple example, if the movie theaters in a town employ 100 people, their direct economic contribution is 100 jobs. But if closing the movie theaters would cause people to spend more time bowling, resulting in 40 new bowling alley jobs, then the economic impact of the movie theaters is only 60 jobs. For some industries, it can be much harder to estimate economic impacts than economic contribution, because it's hard to know how the economy might change if the industries didn't exist.

All of the fishing and processing jobs in Bristol Bay, and their multiplier effects, are economic *impacts*, because they would all disappear if the fishery didn't exist. But not all of the jobs in the retail stores which sell Bristol Bay salmon products are economic impacts, because consumers would buy more of other kinds of fish (and other products) if they couldn't buy Bristol Bay salmon. In this report, we estimate the *economic impacts* of fishing and processing in Bristol Bay, as well as transportation of Bristol Bay products to other states and secondary processing in other states. We estimate the *economic contribution* of distribution and retailing of Bristol Bay salmon. We use the term *economic impacts* to describe the combined effects of all the distribution stages of Bristol Bay salmon, although technically the distribution and retail stage is *economic contribution* rather than *economic impact.*

Payments. In discussing our economic impact modeling assumptions we use the term *payments* to describe payment flows between industries. Economists usually call these *expenditures*.

Output value. We use the term *output value* to mean the total value of the output of an industry, as measured by its total sales. Economists often use the terms *output* or *sales* to refer to the total sales of an industry.

Value increase. We use the term *value increase* or *increase in value* to mean the *increase in value of fish or fish products associated with a particular stage of the harvesting, processing and distribution chain for Bristol Bay salmon*. For example, we say that the "increase in value in processing" for Bristol Bay salmon in 2010 was $225 million, or the difference between the total first wholesale value paid to processors ($390 million) and the total ex-vessel value paid to fishermen ($165 million). Occasionally we use the term *value added* or *adds to value* with the same meaning. This differs from the technical economic definition of "value added" used in the US national income accounting system and in the IMPLAN economic output models. Technically, "value added" refers only to the labor income, proprietor income (profit), and indirect business taxes generated by an industry, and excludes payments to other businesses.

Data Limitations and Assumptions

Reliable data are available for some of the most important measures of the economic importance of the Bristol Bay salmon industry. These include, in particular, data for the "ex-vessel" value of fish catches (the value paid to fishermen), the first wholesale value of fish production, numbers and residency of fishing permit holders, and fish processing employment and wages. These data alone are sufficient to conclusively show that the Bristol Bay salmon industry is very large and economically important, not only for Alaska but also for other states—particularly Washington—and for the United States.

However, data are *not* publically available for the payments by the fishing and processing industries to other industries, the distribution of these payments among different states, the volumes of salmon entering different "downstream" distribution channels, or the payments from downstream industries. It was far beyond the scope of this study to undertake the kinds of detailed surveys of fishermen, processors and downstream industries which would have been necessary to develop statistically reliable estimates for these types of data.

Given this lack of data, to estimate economic impacts of Bristol Bay fishing and processing for the four west coast states, and to estimate downstream economic impacts, we needed to make numerous assumptions about payments by fishermen, processors and downstream industries. To do this we relied on our best judgment, based on many years of observing and studying the industry and on discussions with fishermen, processors and industry suppliers and previous surveys of Bristol Bay fishing permit holders. We document and discuss these assumptions in Appendixes A-D.

It is important to note that not all of our assumptions are equally important for our analysis. For example, if payments by the processing industry to two supplier industries have similar economic impacts in the same location, then it doesn't particularly matter if our assumptions about the allocation of payments between these the two industries are accurate. Similarly, our assumptions about relatively small payments (such as for local Bristol Bay property taxes) matter less than our assumptions about large payments (such as payments to fishing crew and processing workers).

Given the many assumptions we had to make, how accurate are our estimates of economic impacts of the Bristol Bay salmon industry? They are not precise. It would be impossible to measure the magnitude of each kind of economic impact of the Bristol Bay salmon industry in 2010 exactly.

However, our estimates are reasonable measures of the relative scale of the economic impacts of the Bristol Bay salmon industry in 2010, as well as the relative scale of the economic impacts on different states and at different stages of the distribution chain. More importantly, because Bristol Bay salmon catches and prices vary from year to year, the ex-vessel and first wholesale value—which are the key drivers of economic impacts—also vary from year to year (as shown by Figure II-4 in the previous chapter). Given this variability, having more precise estimates of the economic impacts in 2010 would not be particularly helpful in thinking about the longer-term economic importance of the industry. We can be highly confident the economic impacts of the Bristol Bay salmon industry in 2015 will be similar in scale to what they were in 2010. But even if we knew exactly what these economic impacts were in 2010, we couldn't know what its exact economic impacts will be in 2015.

Other Ways in Which the Bristol Bay Salmon Industry is Economically Important

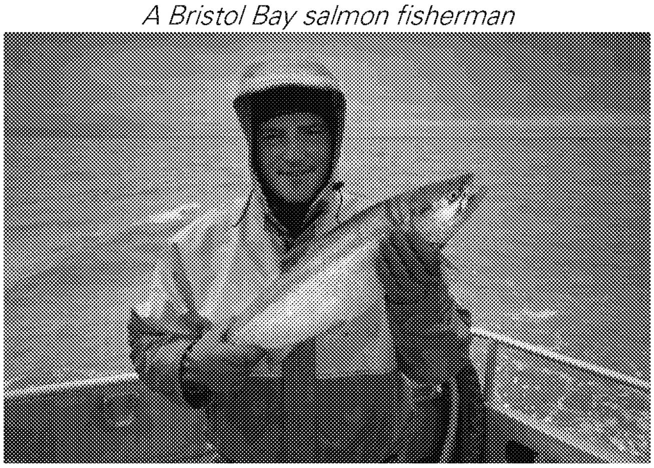
Our analysis for this report applies standard input-output modeling methodology to estimate economic impacts of the Bristol Bay salmon industry. However, standard economic impact analysis does not account for all the ways the Bristol Bay salmon industry is economically important nationally and to west coast states.

The estimated value of Bristol Bay salmon exports in 2010 was $252 million. Although exported Bristol Bay salmon products do not create "downstream" economic impacts in the United States, they contribute significantly to the United States balance of trade, helping to maintain the value of the dollar and pay for imports.

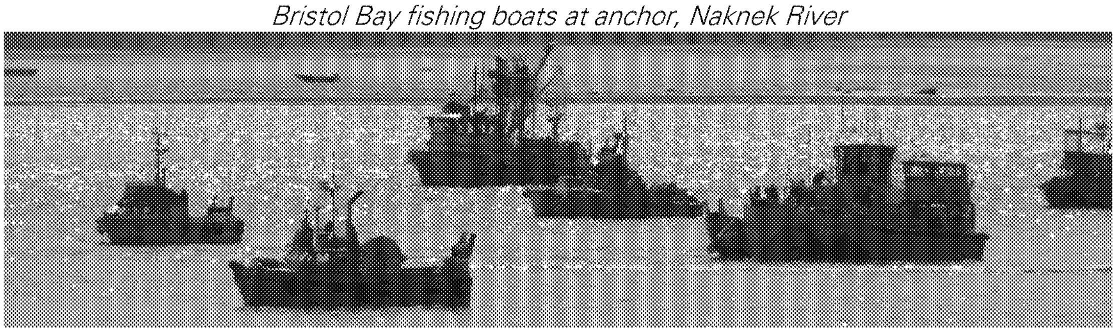
The Bristol Bay salmon industry is a major part of the broader Alaska and Pacific Northwest seafood industry, and pays for an important share of the fixed costs of many fishing and processing operations. Without the Bristol Bay salmon industry, fixed costs would be higher and profits lower in the rest of the seafood industry.

The Bristol Bay salmon industry is a major supporter of infrastructure and utilities in the Bristol Bay region, a major taxpayer, and a very important source of local jobs and income.

A Bristol Bay salmon fisherman



Bristol Bay fishing boats at anchor, Naknek River



IV. DIRECT ECONOMIC IMPACTS OF BRISTOL BAY SALMON FISHING AND PROCESSING

The direct economic impacts of Bristol Bay salmon fishing and processing are the employment, income and output value created in Bristol Bay every summer in the fishing and processing industries. Table IV-1 shows our estimates of these direct economic impacts. In this chapter, we discuss these impacts. Appendix A provides technical details of how we estimated them, as well as sources for all of the data and estimates in this chapter.

Table IV-1

Estimated Direct Economic Impacts of Bristol Bay Salmon Fishing and Processing, 2010

	Total US	AK	WA	OR	CA	Other states
Seasonal employment	11,921	4,369	3,227	553	2,143	1,629
Annual average employment	1,987	728	538	92	357	271
Income ($ million)	143.7	50.1	48.2	8.1	18.9	18.4
Output value ($ million)	389.7	126.7	198.5	13.4	19.4	31.7

Sources: See discussion in Appendix A. Note: Direct employment and income impacts are allocated to the states in which workers were residents. Direct output value impacts are allocated to the states to which payments were made.

Bristol Bay Fishing and Processing Employment

Almost 12,000 people worked in Bristol Bay salmon fishing and processing during the 2010 salmon season (Table IV-2 and Figure IV-1). About 7000 worked in fishing and almost 5,000 worked in processing.

Direct employment in the Bristol Bay salmon industry is widely spread across several states, employing large numbers of not only Alaska residents but also Washington, Oregon and California residents. Alaska residents held the most fishing jobs (about 4400) followed by Washington residents (about 3200). In contrast, California residents held the most processing jobs (about 1800) followed by Washington residents (about 1300).

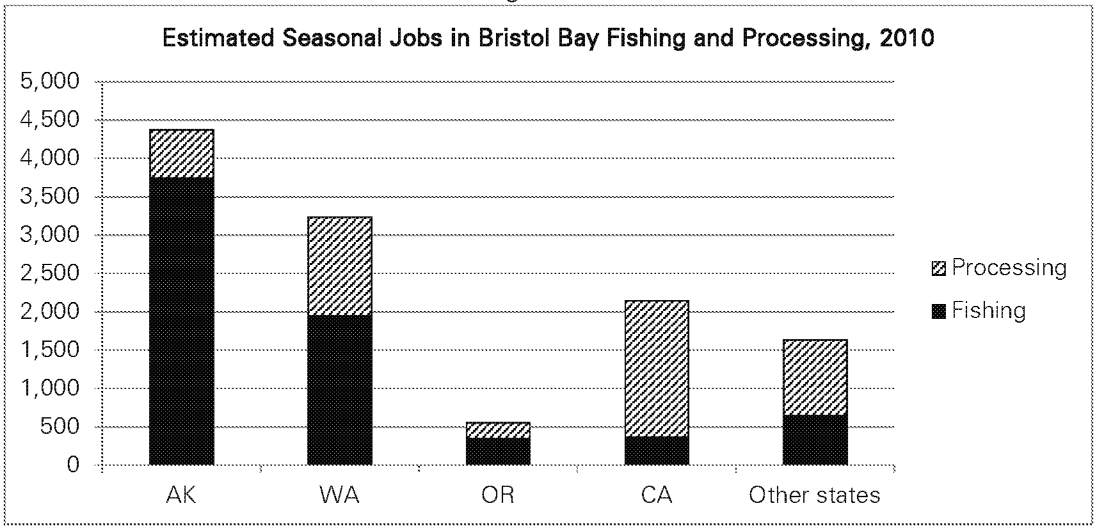
Table IV-2

Estimated Seasonal Jobs in Bristol Bay Salmon Fishing & Processing, 2010

	Total	AK	WA	OR	CA	Other states
Fishing	7,035	3,734	1,948	345	362	646
Processing	4,886	635	1,279	208	1,781	983
Total	**11,921**	**4,369**	**3,227**	**553**	**2,143**	**1,629**

Note: Estimates are by workers' state of residence.

Figure IV-1



Employment impacts are generally expressed in terms of annual average employment. To estimate annual average employment in Bristol Bay salmon fishing and processing, we assumed that fishing and processing jobs last two months on average. Thus our annual average employment estimates (Table IV-3) are simply one-sixth of our seasonal employment estimates.

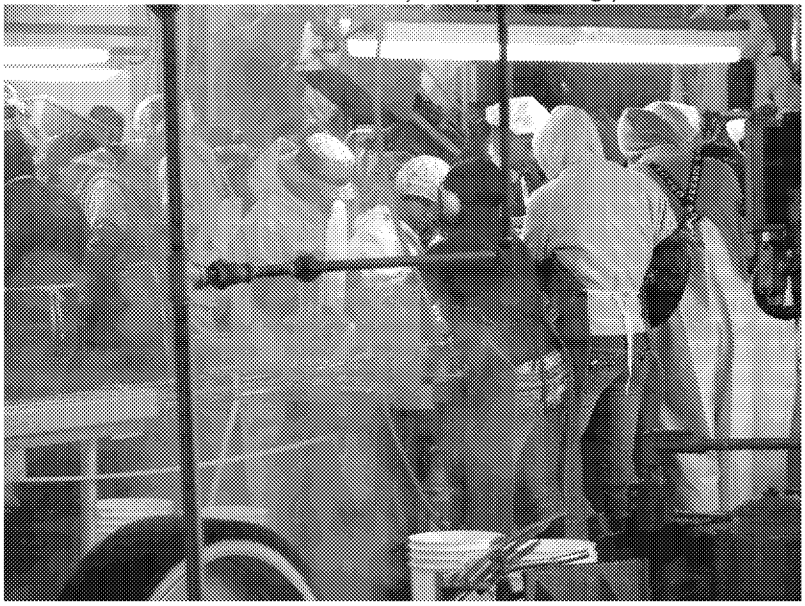
Table IV-3

Estimated Annual Average Employment in Bristol Bay Salmon Fishing & Processing, 2010

	Total	AK	WA	OR	CA	Other states
Fishing	1,173	622	325	57	60	108
Processing	814	106	213	35	297	164
Total	**1,987**	**728**	**538**	**92**	**357**	**271**

Note: Estimates are by workers' state of residence.

Workers at a Bristol Bay fish processing plant



Bristol Bay Fishing and Processing Income

Bristol Bay fishermen and processing workers earned a total of about $144 million in 2010. Fishermen earned much more on average (about $15,600 per seasonal job) than processing workers (about $6,950 per seasonal job). Fishermen's earnings include earnings of both crew (who earn relatively less on average) and permit holders (who earn relatively more on average).

Table IV-4

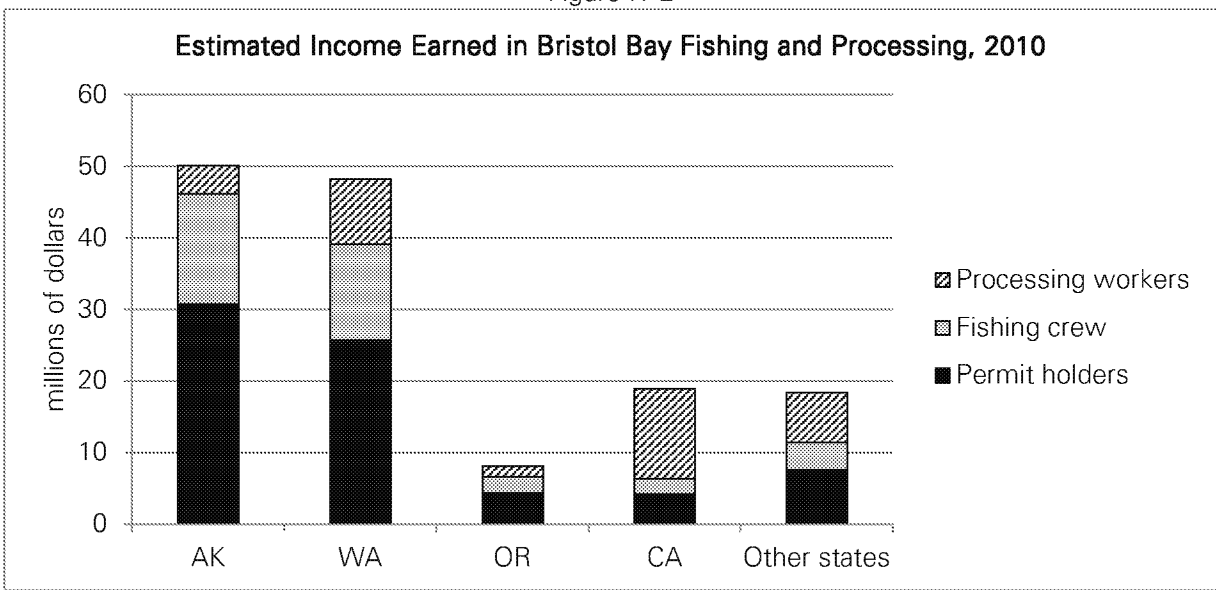
Estimated Income Earned in Bristol Bay Salmon Fishing and Processing, 2010 ($ millions)

	Total	AK	WA	OR	CA	Other states
Fishing crew	37.1	15.5	13.4	2.2	2.1	3.8
Permit holders*	72.7	30.8	25.8	4.4	4.2	7.6
Fishermen, total	*109.7*	*46.2*	*39.2*	*6.6*	*6.3*	*11.4*
Processing workers	34.0	3.9	9.0	1.5	12.6	6.9
Total	**143.7**	**50.1**	**48.2**	**8.1**	**18.9**	**18.4**

*Estimated permit holder net income after expenses. Note: Estimates are by state of residence of income recipients.

Even though fewer Washington residents worked in Bristol Bay, Washington residents earned almost as much income working in Bristol Bay—almost $50 million—as Alaska residents. This is because Washington residents earned much more on average from fishing ($20,100) than Alaska residents ($12,400). (Appendix Table A-3 provides more details about gross earnings of permit holders, by state).

Figure IV-2



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Bristol Bay Output Value

The total output value of Bristol Bay fishing and processing in 2010—equal to the first wholesale value paid to processors for all the salmon products produced in Bristol Bay—was $390 million.

Table IV-5

Estimated Direct Output Value of Bristol Bay Salmon Fishing and Processing, 2010 (millions of dollars)

	Total	AK	WA	OR	CA	Other states
Fishing	165.2	83.3	55.6	7.2	6.8	12.3
Processing	224.5	43.4	142.9	6.3	12.6	19.4
Total	389.7	126.7	198.5	13.4	19.4	31.7

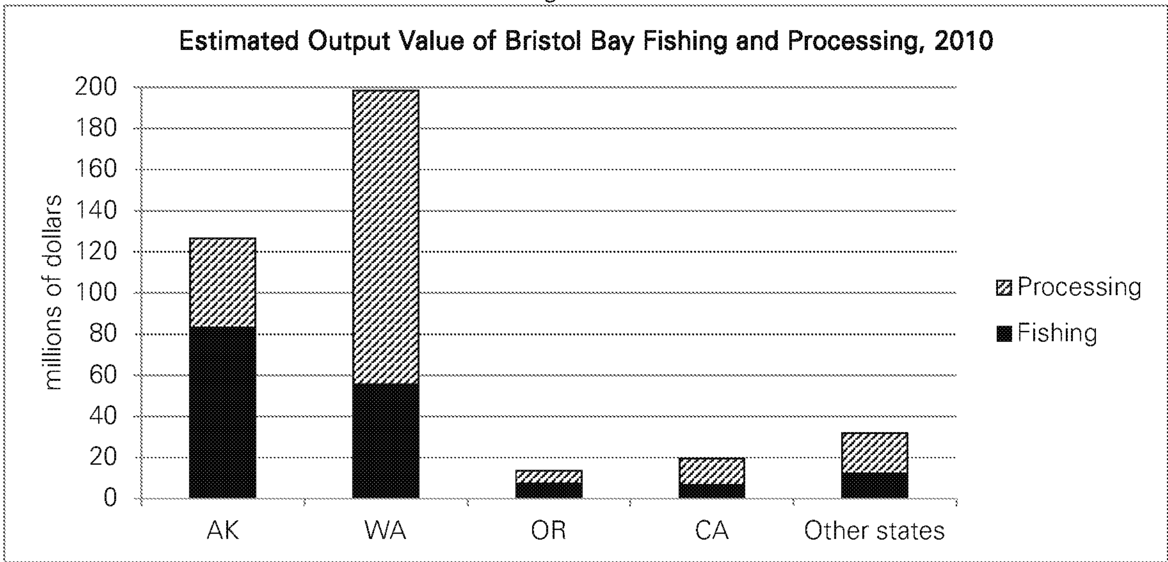
Note: Impacts are allocated to the states to which estimated payments from output value were made.

Of this, fishing contributed $165 million in output value—the ex-vessel value paid to fishermen. Processing contributed the remaining $225 million.

From one perspective, because Bristol Bay fishing and processing occurs in Alaska, all of this output value was created in Alaska. From a different perspective, however, it was created in the states that provided the fishermen, processing workers, supplies and services that created the value. Both perspectives are useful. For the purposes of this study, we adopted the second perspective, and allocated output value to the states to which estimated payments from output value were made—a measure of their contribution to output value.

Note that defined in this way, Washington contributed the greatest share of output value, primarily because of its contributions to the value created in processing. Although Bristol Bay salmon processing takes place in Alaska, it is (from our second perspective) more a Washington industry than an Alaska industry—because all of the large processing companies are based in Washington, such a large share of their supplies and services are purchased from Washington, and many of the fishermen are from Washington.

Figure IV-3



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V. MULTIPLIER ECONOMIC IMPACTS OF BRISTOL BAY SALMON FISHING AND PROCESSING

The multiplier economic impacts of Bristol Bay salmon fishing and processing are the indirect and induced impacts on other industries driven by payments of fishermen and processors to businesses and households. This chapter describes our estimates of multiplier economic impacts. Appendix B provides technical details of how we estimated them and sources for all of the data and estimates in this chapter.

Estimated Payments of Bristol Bay Fishermen and Processors

In 2010, Bristol Bay salmon processors were paid $390 million for the salmon products they produced in the Bristol Bay fishery. Estimating the payments from this value, and what states they went to, was the first step in our analysis of multiplier impacts. Table V-1 summarizes these estimates, which we based on State of Alaska data for processing workers' and permit holders' earnings, earlier studies of permit holders' costs, discussions with industry sources, and our best judgment.

Table V-1

Assumed Direct Payments from Bristol Bay Fishing and Processing, by State, 2010 ($ millions)

		Payments by State				
	Total	AK	WA	OR	CA	Other
Total first wholesale value FOB Bristol Bay (a)	389.7					
Value added in Bristol Bay by processors (a)	224.5					
Ex-vessel value paid to permit holders (a)	165.2					
Payments by processors (b)	**224.5**	**43.4**	**142.9**	**6.3**	**12.6**	**19.4**
Labor	34.0	3.9	9.0	1.5	12.6	6.9
Tendering	31.5	6.3	22.1	3.2		
Maintenance	29.2	2.9	26.3			
Packaging	23.3	0.0	14.0			9.3
Fishermen's support services	18.1	5.4	11.1	1.6		
Variable supplies	10.5	2.1	7.4			1.1
State & local taxes	9.9	9.9				
Fuel	7.4	1.9	5.6			
Utilities	7.0	7.0				
Insurance	5.4	0.0	5.4			
Food	4.7	0.5	4.2			
Air travel	4.7	0.2	4.4			
Fixed supplies	3.5	0.4	2.8			0.4
Rents & leases	1.2	1.2				
Other payments and returns to investment	34.1	1.7	30.7			
Payments by permit-holders (c)	**165.2**	**83.3**	**55.6**	**7.2**	**6.8**	**12.3**
Crew shares (excluding skipper)	37.1	15.5	13.4	2.2	2.1	3.8
Maintenance (routine & unexpected)	7.6	6.3	1.3			
Nets (hanging, repair, and web)	6.4	5.3	1.1			
Vessel and gear replacement	6.1	0.5	5.6			
Insurance (P&I, hull, lay-up)	5.2	2.0	2.7	0.2	0.2	0.3
Fuel, oil, & lubricants	5.1	5.1				
Miscellaneous gear & supplies	5.0	2.9	2.1			
Transportation	4.9	2.2	1.7	0.3	0.3	0.4
Raw fish tax	4.8	4.8				
Food	4.1	2.7	1.4			
Moorage, storage, and haul-out	3.0	3.0				
Administrative services	1.7	0.7	0.6	0.1	0.1	0.2
Property tax	0.7	0.7				
Annual permit fee	0.6	0.6				
Annual vessel license fee	0.2	0.2				
Retained by permit holders (d)	72.7	30.8	25.8	4.4	4.2	7.6

(a) Estimated direct output value reported in Table IV-5.
(b) Payments from value added in Bristol Bay by processors, excluding payments to permit holders for fish.
(c) Payments from ex-vessel value paid to permit holders.
(d) Returns to permit holders' labor, management and investment

Figures V-1 and V-2 show how the amounts and composition of payments differed between states. Washington received the largest share of the payments, primarily because most processing costs and processors' returns to investment went to Washington. Alaska received the second largest share of the payments, mostly for fishing crew, other fishing costs, permit holder net earnings, and processing costs.

Figure V-1

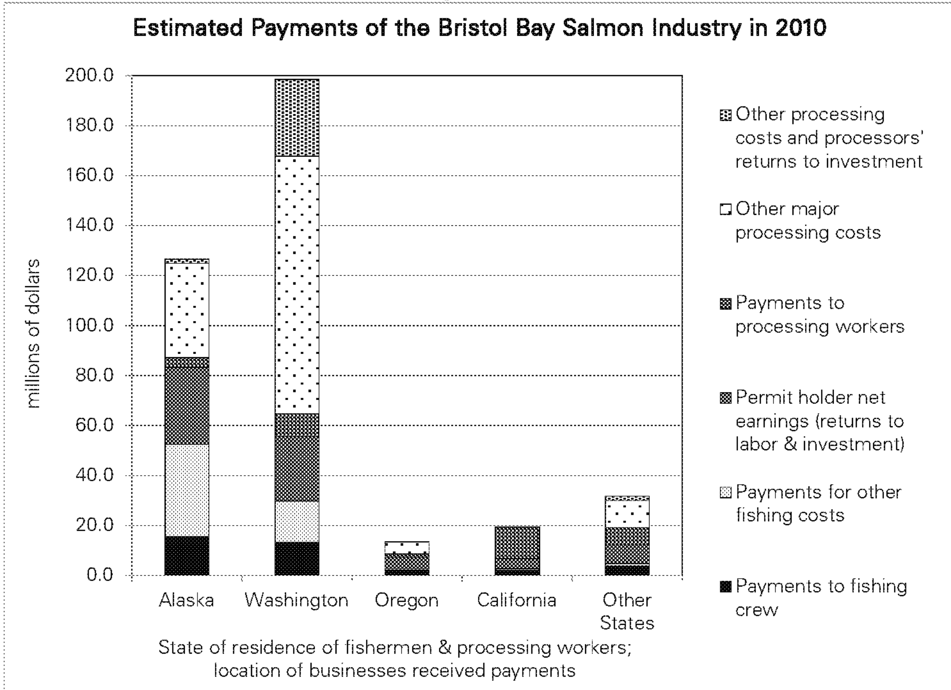
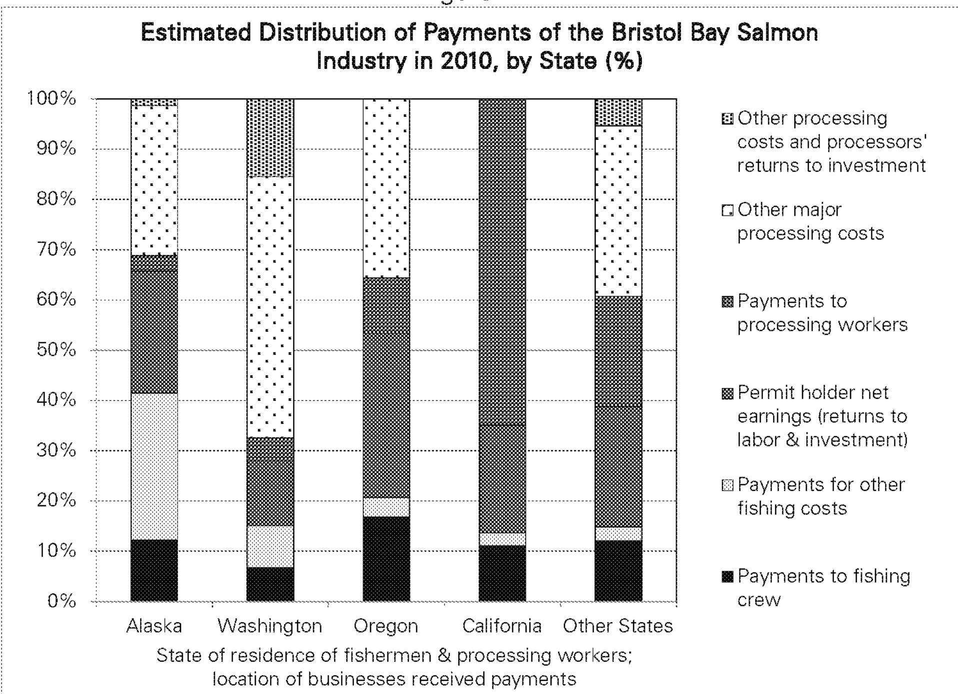


Figure V-2



The estimates of payments by state shown in Figure V-1 are among the most important analysis and findings of this report, because it is these payments which drive the multiplier impacts of Bristol Bay fishing and processing. The fact that such a large share of the payments from fishing and processing goes to Washington helps to explain why the economic impacts of the Bristol Bay salmon fishery are so large and important for Washington.

Estimated Multiplier Impacts of Bristol Bay Fishing and Processing

We used IMPLAN input-output models to estimate the multiplier economic impacts (indirect and induced impacts) resulting from payments to different states to calculate the multiplier economic impacts of Bristol Bay salmon fishing and processing in the United States and in the four west coast states. Table V-2 and Figures V-3 through V-5 summarize these estimates.

Table V-2

Estimated Economic Impacts of Bristol Bay Salmon Fishing and Processing, 2010

Measure	Type of impact	Total US	Alaska	Washington	Oregon	California	Other states
Annual average employment	Direct impact	1,987	728	538	92	357	271
	Indirect impact	2,370	761	1,212	57	4	336
	Induced impact	3,482	578	1,025	106	245	1,529
	Multiplier impact	5,852	1,338	2,237	163	249	1,865
	Total impact	7,839	2,067	2,775	255	606	2,137
Income ($ millions)	Direct impact	143.7	50.1	48.2	8.1	18.9	18.4
	Indirect impact	111.6	38.0	54.0	2.7	0.3	16.7
	Induced impact	156.4	24.0	43.7	4.0	11.9	72.9
	Multiplier impact	268.0	62.0	97.6	6.7	12.1	89.6
	Total impact	411.7	112.1	145.8	14.8	31.0	108.0
Output value ($ millions)	Direct impact	389.7	126.7	198.5	13.4	19.4	31.7
	Indirect impact	310.7	88.4	155.5	7.1	0.7	58.9
	Induced impact	490.5	72.6	132.2	11.7	35.8	238.2
	Multiplier impact	801.2	161.0	287.8	18.9	36.5	297.0
	Total impact	1190.9	287.7	486.3	32.3	55.9	328.7

We estimated that, for the United States nationally, Bristol Bay salmon fishing and processing generated multiplier impacts in other industries totaling 5800 jobs (annual average employment), $268 million in income, and $801 million in output value. The distribution of multiplier impacts between states was similar to the distribution of the spending which drove the multiplier impacts (Figure V-1). The multiplier impacts were greatest in Washington (more than one-third of total multiplier impacts), followed by Alaska (about one-fourth).

Figure V-3

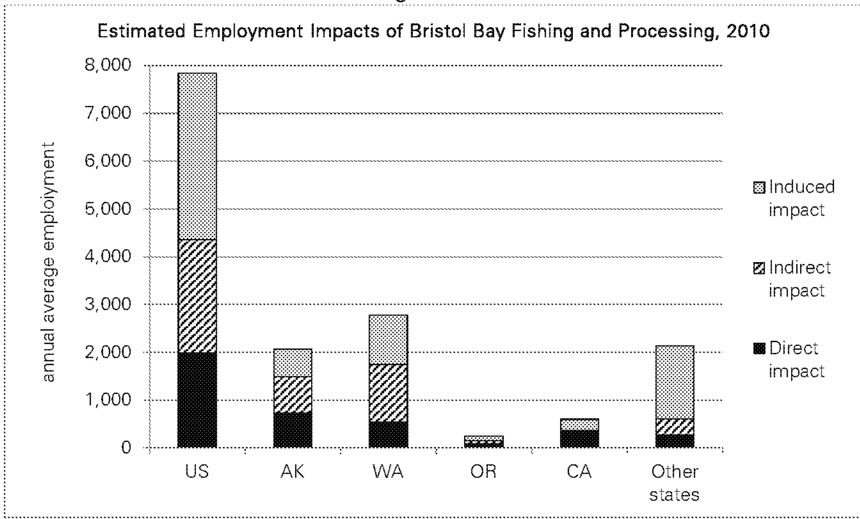


Figure V-4

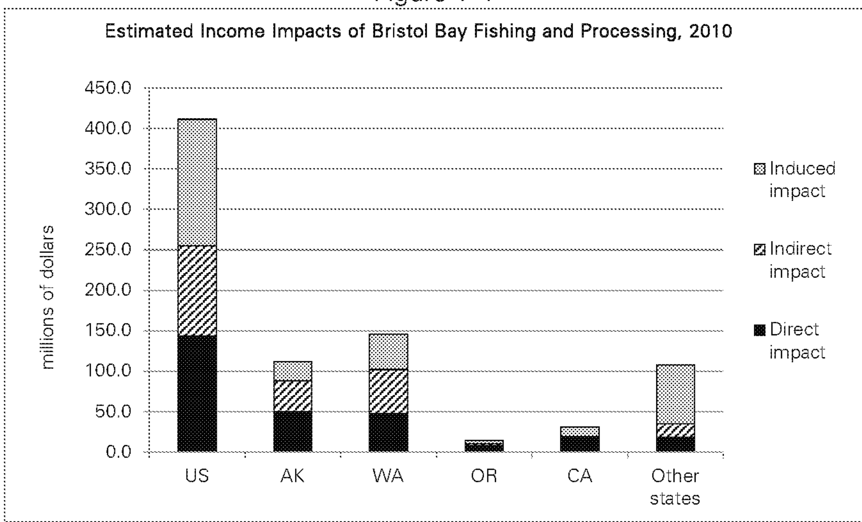
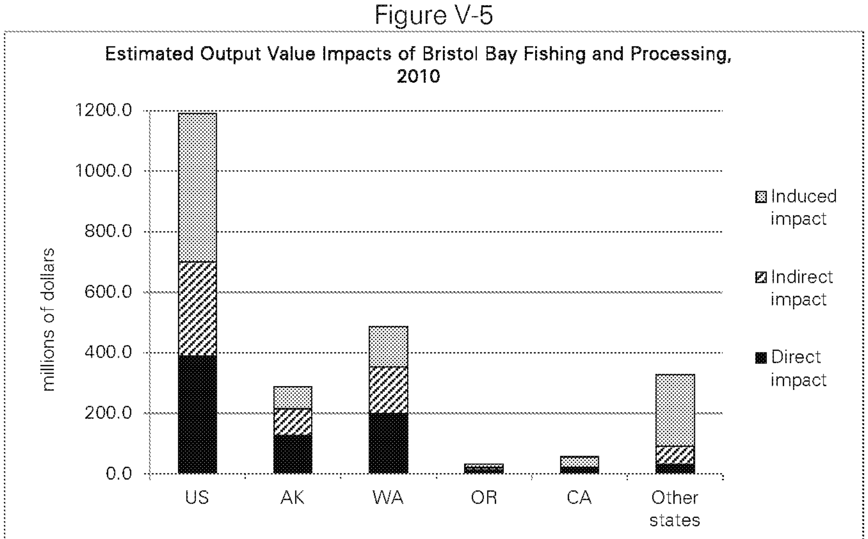


Figure V-5



Economic Multipliers for Bristol Bay Fishing and Processing

Economists use the term "multiplier" to refer to the ratio of indirect, induced, or multiplier (indirect + induced) output value impacts to direct output value impacts. The output value multipliers show how much indirect, induced or multiplier (indirect + induced) output value is created in the economy for every dollar of direct output value.

Table V-3 shows the output value multipliers for Bristol Bay salmon fishing and processing implied by our economic impact analysis for 2010. Looking at the bottom row, every dollar of direct output value in Bristol Bay salmon fishing and processing created an estimated additional $2.06 in multiplier impacts. The output value multipliers are highest for the United States and lowest for Alaska. This is because the output value multipliers measure the additional output value created as payments ripple through the economy. In general, the larger an economy, the greater this ripple effect of payment flows within the economy.

The output value multipliers are smallest for Alaska because a greater share of the payments of businesses and households in Alaska go outside the state than in than in larger states or for the United States as a whole.

Table V-3

Estimated Output Value Multipliers for Bristol Bay Salmon Fishing and Processing, 2010

Multiplier	US	AK	WA	OR	CA
Ratio of indirect impacts to direct impacts	0.80	0.70	0.78	0.53	0.04
Ratio of induced impacts to direct impacts	1.26	0.57	0.67	0.87	1.85
Ratio of multiplier impacts to direct impacts	2.06	1.27	1.45	1.41	1.88

Figure V-3

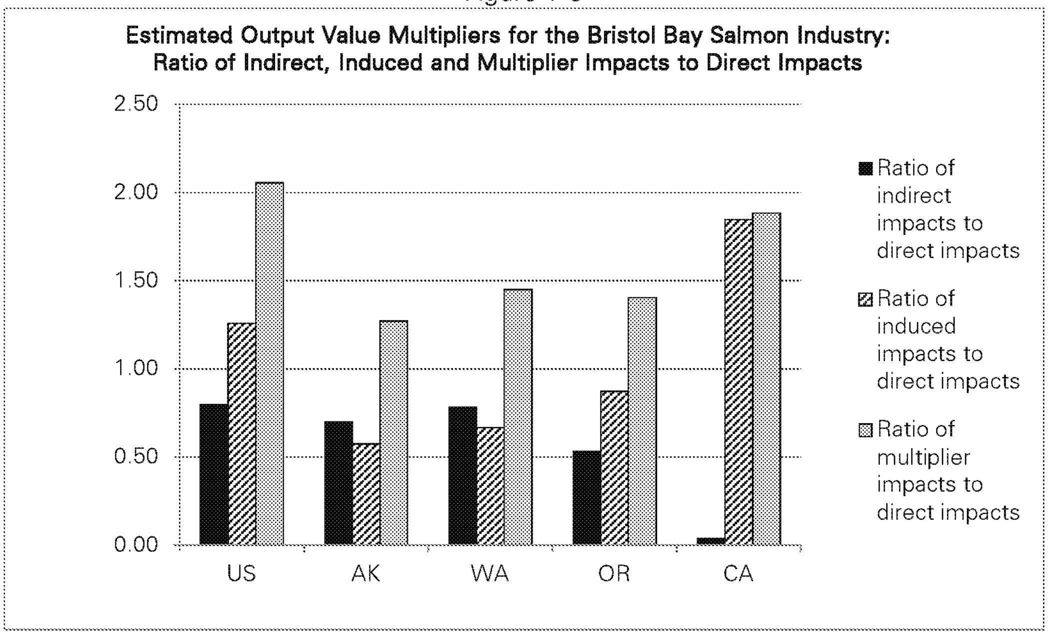


Table V-4 shows the ratio of nationwide (total US) multiplier employment to direct employment in Bristol Bay salmon fishing and processing. For every direct job created by the Bristol Bay salmon fishing and processing, almost three multiplier jobs are created in other industries across the United States.

Table V-4
Ratio of Nationwide Multiplier Employment to Direct Employment
in Bristol Bay Salmon Fishing & Processing, 2010

Type of impact	Ratio
Ratio of indirect impacts to direct impacts	1.19
Ratio of induced impacts to direct impacts	1.75
Ratio of multiplier impacts to direct impacts	2.95

Helicopter transportation to Bristol Bay floating processors
Is a multiplier impact of Bristol Bay salmon processing

VI. SELECTED DOWNSTREAM ECONOMIC IMPACTS OF THE BRISTOL BAY SALMON INDUSTRY

The downstream economic impacts of the Bristol Bay salmon industry are those driven by the transportation, secondary processing, warehousing, distribution and retailing of Bristol Bay salmon which occurs in the United States. For this study, we estimated the following downstream economic impacts:

- *Shipping to other states and secondary processing:* We estimated economic impacts of marine transportation of frozen and canned salmon, secondary processing of frozen salmon, and warehousing and labeling of canned salmon for the United States, Washington and Oregon.

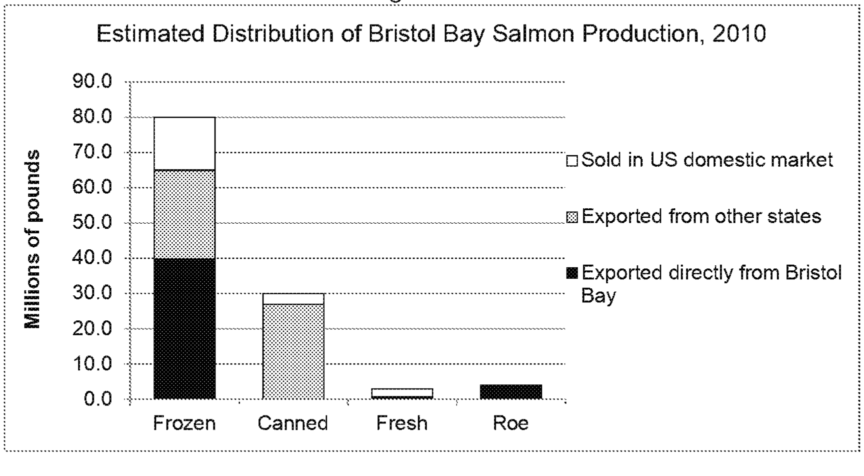
- *Distribution and retailing:* We estimated economic contributions of nationwide transportation, wholesaling and retailing of Bristol Bay salmon products in stores and restaurants.

This chapter discusses our estimates of downstream economic impacts. Appendix C provides technical details of how we estimated them, as well as sources for the data and estimates of economic impacts in this chapter. Appendix E discusses the estimates presented in this chapter of Bristol Bay salmon export value and United States consumption of frozen salmon.

End Markets for Bristol Bay Salmon Products

The first step in our analysis of downstream economic impacts of the Bristol Bay salmon industry was to estimate end markets for Bristol Bay salmon. In 2010, about half of Bristol Bay frozen salmon was exported directly from Bristol Bay, primarily to Japan and China. We assumed the rest was shipped to Washington for secondary processing, including filleting, portioning, re-boxing and smoking. About three-fifths of these products were also exported. The rest—about one-fifth of total Bristol Bay frozen salmon production—was sold in the US market.

Figure VI-1



All Bristol Bay canned salmon is shipped to warehouses in Washington and Oregon where it is stored, labeled and sold by processors over the course of the year, mostly to the United Kingdom and other export markets. We assumed that most of the small volume of Bristol Bay fresh salmon is sold in the

United States, and that all of the roe production is exported. Overall, about 83% of the total volume of Bristol Bay salmon production (all products combined) is exported, and about 17% is sold in the United States market.

Table VI-1

Assumed End-Markets for Bristol Bay Salmon Production, 2010

		Frozen	Canned	Fresh	Roe	Total
Millions of pounds	Total production	80.0	29.9	2.9	4.0	116.7
	Exported directly from Bristol Bay	39.8	0.0	0.5	4.0	44.3
	Shipped to other states	**40.2**	**29.9**	**2.4**	**0.0**	**72.4**
	Exported from other states	25.2	26.9	0.2	0.0	52.2
	Sold in US domestic market	**15.0**	**3.0**	**2.2**	**0.0**	**20.2**
Share of production	Total production	100%	100%	100%	100%	100%
	Exported directly from Bristol Bay	50%	0%	19%	100%	38%
	Shipped to other states	**50%**	**100%**	**81%**	**0%**	**62%**
	Exported from other states	31%	90%	6%	0%	45%
	Sold in US domestic market	**19%**	**10%**	**76%**	**0%**	**17%**
Other assumptions	Mode of transportation to other states	Sea	Sea	Air		
	Assumed states to which products were initially shipped	100% to Washington	50% to Washington 50% to Oregon			
	Types of secondary processing and other handling prior to distribution to retailers	Filleting, portioning, reboxing, smoking	Warehousing & labeling			

Sources: Alaska production data, US export data, and discussions with industry sources, as discussed in Appendix C.

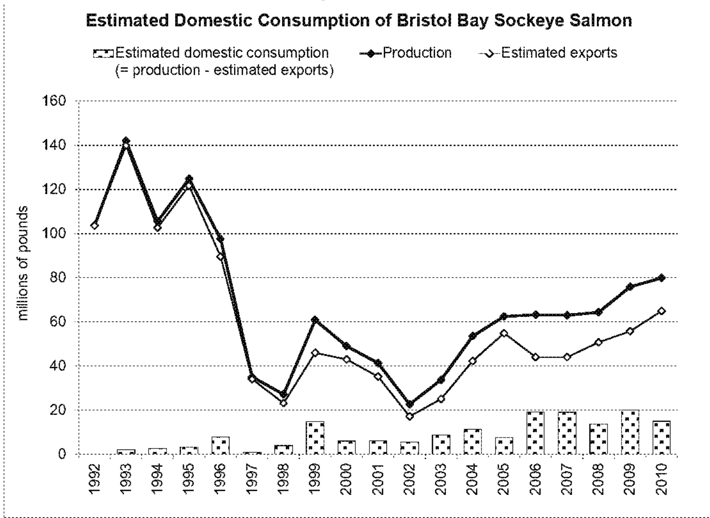
Until the late 1990s, almost all Bristol Bay frozen salmon was exported, mostly to Japan. Since then, although the share of Bristol Bay frozen salmon sold in the United States market remains relatively small, it has been gradually rising over time (Figure VI-2). Factors contributing to the growth in the domestic market for Bristol Bay sockeye have included the development of new product forms, particularly fillets and portions, and sustained and effective marketing by Alaska processors and the Alaska Seafood Marketing Institute (ASMI). As these continue, it is likely that the share of Bristol Bay salmon consumed by Americans will continue to grow—increasing the downstream economic impacts and contributions of Bristol Bay salmon.

Downstream jobs supported partly by Bristol Bay salmon

Forklift operator at Salmon Terminals canned salmon warehouse, Auburn, Washington

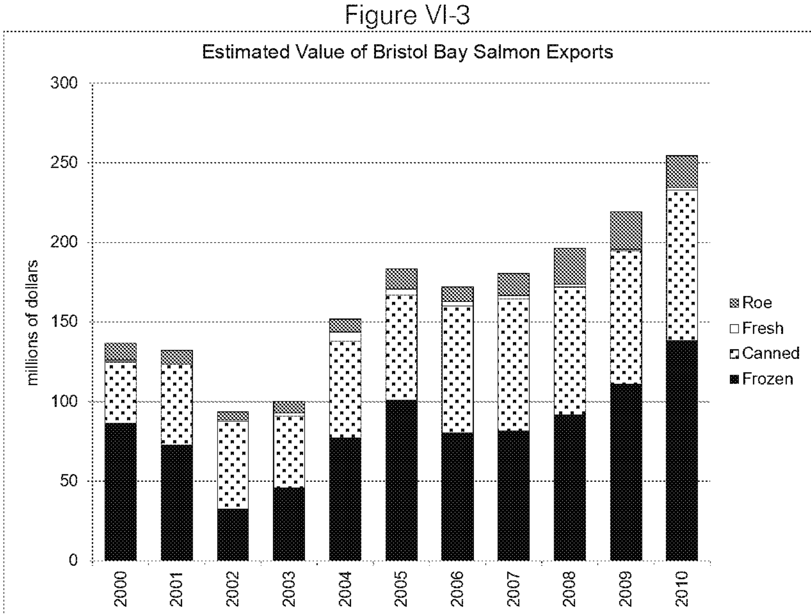
Retail fish counter employee

Figure VI-2



As shown in Figure VI-3, the estimated value of Bristol Bay salmon exports has risen dramatically since 2002 as prices for Bristol Bay sockeye salmon have risen. In 2010, the estimated total value of Bristol Bay salmon exports was $252 million, or approximately 74% of the value of total US sockeye salmon exports, 28% of the value of total US salmon exports (all species), and 6% of the value of total US edible fish exports (all species).

Figure VI-3

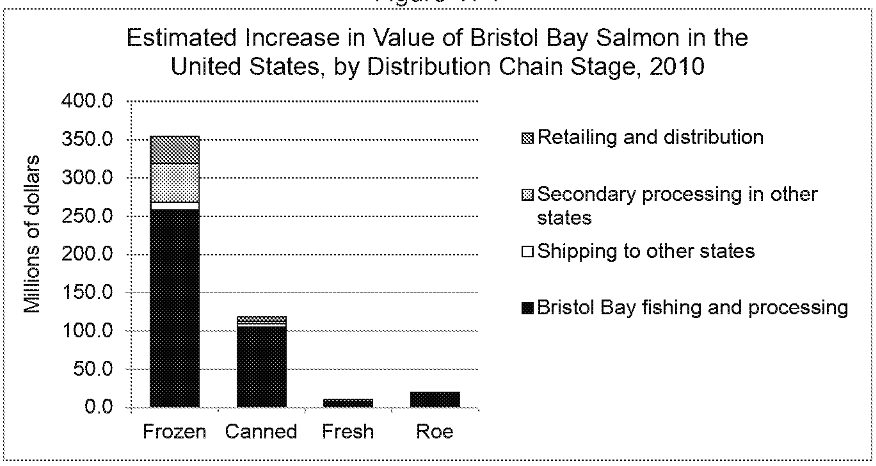


The high export share of Bristol Bay sockeye salmon reduces its downstream economic contribution in domestic distribution and retailing. But Bristol Bay salmon exports are economically important to the United States in a different way: they contribute to the United States balance of trade, helping to maintain the value of the dollar and pay for imports. In particular, they help to offset the United States' massive seafood trade deficit (US seafood imports in 2010 totaled $14.8 billion compared with total exports of $4.4 billion).

Downstream Increases in Value of Bristol Bay Salmon

The economic impacts of the Bristol Bay salmon industry are driven by the payments associated with each distribution chain stage which go to businesses and to households (as payments to workers and profits of owners). Collectively these payments are equal to the increase in value associated with each stage. Figure VI-4 and Table VI-2 show our estimates of these increases in value.

Figure VI-4



Estimated Increase in Value of Bristol Bay Salmon in the United States, by Distribution Chain Stage, 2010

Table VI-2

Estimated Increase in Value of Bristol Bay Salmon in the United States, by Distribution Chain Stage, 2010

	Distribution chain stage	Primary product form: Frozen	Canned	Fresh	Roe	Total
Product volume entering stage (millions of lbs, primary product weight basis)	Bristol Bay fishing and processing	80.0	29.9	2.9	4.0	116.7
	Shipping to other states	40.2	29.9	2.9		72.4
	Secondary processing in other states	40.2	29.9			70.1
	Retailing and distribution	15.0	3.0	2.2		20.2
Increase in value/lb in stage (primary product weight basis)	Bristol Bay fishing and processing (= first wholesale price)	$3.23	$3.52	$2.11	$5.03	
	Shipping to other states	$0.26	$0.13	$0.50		
	Secondary processing in other states	$1.25	$0.10			
	Retailing and distribution	$2.37	$1.88			
Increase in value in stage ($ millions)	Bristol Bay fishing and processing	258.3	105.4	6.1	19.9	389.7
	Shipping to other states	10.4	4.0	1.4		15.9
	Secondary processing in other states	50.4	3.1			53.5
	Retailing and distribution	35.6	5.6	2.9		44.1
	Total	**354.7**	**118.1**	**10.4**	**19.9**	**503.1**
Share of total increase in value	Bristol Bay fishing and processing	73%	89%	59%	100%	77%
	Shipping to other states	3%	3%	14%	0%	3%
	Secondary processing in other states	14%	3%	0%	0%	11%
	Retailing and distribution	10%	5%	27%	0%	9%
	Total	**100%**	**100%**	**100%**	**100%**	**100%**

Note that 77% of the total estimated increase in value—and the corresponding payments—occurs in Bristol Bay fishing and processing. Only about 23% of the estimated increase in value occurs in downstream stages of the distribution chain. For this reason, the estimated downstream economic impacts and contribution are much smaller than the estimated economic impacts of Bristol Bay salmon fishing and processing.

Estimated Downstream Economic Impacts of Marine Transportation and Secondary Processing

Table VI-3 summarizes the estimated payments generated in marine transportation and selected secondary processing activities of Bristol Bay sockeye salmon in 2010. The largest of these are in secondary processing of frozen salmon, mostly in Washington.

Table VI-3

Estimated Payments Generated in Selected Shipping and Secondary Processing, 2010 ($ millions)

Activity	US	WA	OR
Marine transportation of frozen salmon	10.4	10.4	
Frozen salmon secondary processing	50.4	42.2	
Marine transportation of canned salmon	4.0	2.0	2.0
Canned salmon warehousing and labeling	3.1	1.6	1.6
Total	67.9	56.1	3.5

We used IMPLAN input-output models to estimate the multiplier economic impacts (indirect and induced impacts) resulting from these estimated payments in the United States, Washington and Oregon. Table VI-4 summarizes these estimates.

Table VI-4

Estimated Downstream Economic Impacts of Selected Shipping and Secondary Processing, 2010

Measure	Type of impact	Total US	Washington	Oregon
Annual average employment	Direct effect	191	156	15
	Indirect effect	243	103	12
	Induced effect	319	126	12
	Multiplier effect	563	229	24
	Total effect	754	385	39
Income ($ millions)	Direct effect	13.1	11.0	0.9
	Indirect effect	15.8	6.3	0.5
	Induced effect	14.3	5.4	0.4
	Multiplier effect	30.1	11.7	1.0
	Total effect	43.2	22.7	1.8
Output value ($ millions)	Direct effect	67.8	56.0	3.5
	Indirect effect	66.2	21.1	1.3
	Induced effect	44.8	16.3	1.3
	Multiplier effect	111.0	37.4	2.6
	Total effect	178.8	93.5	6.2

Estimated Downstream Economic Contributions of Distribution and Retailing of Bristol Bay Sockeye Salmon Products

Table VI-5 summarizes the estimated payments generated by nationwide distribution and retailing of Bristol Bay salmon products in 2010. Recall, as discussed in Chapter III, that these estimates are based on the simple and conservative assumption that distribution and retailing increases the value of Bristol Bay salmon products by an average of 50%.

Table IV-5

Estimated Payments Generated in Nationwide Distribution and Retailing of Bristol Bay Salmon Products, 2010 ($ millions)

Activity	US
Distribution & retailing of frozen salmon	35.6
Distribution & retailing of canned salmon	5.6
Air transportation of fresh salmon	1.4
Distribution & retailing of fresh salmon	2.9

We used the national IMPLAN input-output model to estimate the multiplier economic contributions (indirect and induced contribution) resulting from these estimated payments. Table IV-6 summarizes these estimates. They should be interpreted as estimates of *what the associated jobs, income and output value would have been if the average increase in value were 50%*, rather than as a precise estimate of what they were. It is likely that the actual economic contributions associated with distribution and retailing in 2010 were at least as high as our estimates, and possible that they were significantly higher. Recall that these are estimated economic *contributions* rather than impacts, because not all of the economic activity currently associated with distribution and retailing Bristol Bay sockeye salmon would necessarily disappear if Bristol Bay salmon didn't exist–because consumers would buy more of other kinds of fish and other products if they couldn't buy Bristol Bay salmon.

Table IV-6

Estimated Downstream Economic Contributions of Distribution and Retailing of Bristol Bay Salmon Products in the United States, 2010

Measure	Type of contribution	Activity
Annual average employment	Direct contribution	787
	Indirect contribution	112
	Induced contribution	312
	Multiplier contribution	425
	Total contribution	1,212
Income ($ millions)	Direct contribution	22.7
	Indirect contribution	5.6
	Induced contribution	14.0
	Multiplier contribution	19.6
	Total contribution	42.3
Output value ($ millions)	Direct contribution	45.5
	Indirect contribution	16.9
	Induced contribution	43.8
	Multiplier contribution	60.8
	Total contribution	106.3

VIII. CONCLUSIONS

The Bristol Bay sockeye salmon fishery is the world's most valuable wild salmon fishery, and typically supplies almost half of the world's wild sockeye salmon. In 2010, Bristol Bay salmon fishermen harvested 29 million sockeye salmon worth $165 million in direct harvest value alone. That represented 35% of the total Alaska salmon harvest value, and was greater than the total value of fish harvests in 41 states. Salmon processing in Bristol Bay increased the value by $225 million to a total first wholesale value after processing of $390 million. The total value of Bristol Bay salmon product exports in 2010 was about $250 million, or about 6% of the total value of all U.S. seafood exports.

In 2010, Bristol Bay salmon fishing and processing and its downstream and multiplier impacts created annual average employment of almost 10,000, more than $500 million in income, and $1.5 billion in output value in the United States. The figures and tables at the end of this chapter provide details of our estimates of the direct and multiplier impacts and contributions of the Bristol Bay salmon industry in 2010.

During the 2010 salmon season, almost 12,000 people worked in Bristol Bay salmon fishing and processing. About 7,000 worked in fishing and almost 5,000 worked in processing.

The economic importance of the Bristol Bay salmon industry goes well beyond the jobs, income and output value created by the fishing and processing which happens in Bristol Bay. More jobs, income and output value are created in other industries as Bristol Bay fishermen and processors purchase supplies and services and spend the money they earn. Still more jobs, income and output value are created in downstream industries as Bristol Bay salmon are shipped to other states, undergo further processing, and are sold in stores and restaurants across the United States.

Although Bristol Bay fishing and processing take place in Alaska, about four-fifths of the economic impacts and contributions occur outside Alaska; about one-third occur in Washington. This is because almost two-thirds of the people working in Bristol Bay are from other states; the major processors are all based in Washington; most of the supplies and services are purchased from Washington; most of the multiplier or ripple effects occur in other states; and downstream economic impacts occur in other states, and are concentrated in Washington.

Because most of the total economic impacts of the Bristol Bay salmon industry occur outside Alaska, previous studies which focused only on impacts which occur in Alaska greatly understated its national economic importance. It is natural and reasonable for economic studies done by and for Alaskans to focus on the economic importance of the industry for Alaska. But from a national perspective, it is the national economic impacts which matter.

Multiplier economic impacts of Bristol Bay fishing and processing account for the largest share of the total economic impacts of the Bristol Bay salmon industry. For every dollar of direct output value created in Bristol Bay fishing and processing, more than two additional dollars of output value are created in other industries, as payments from the Bristol Bay fishery ripple through the economy. These payments create almost three jobs for every direct job in Bristol Bay fishing and processing.

The downstream economic impacts of the Bristol Bay salmon industry currently represent less than one-fifth of the total impacts. This is because only about 17% of Bristol Bay salmon is consumed in the United States: almost two-fifths is exported directly from Bristol Bay and another two-fifths is exported from other states.

The downstream economic impacts of Bristol Bay sockeye salmon are likely to grow over time. United States domestic consumption of Bristol Bay frozen sockeye salmon products has been growing—and is likely to continue to grow—as a result of sustained and effective marketing by the industry, new product development and other factors.

Exports of Bristol Bay salmon benefit the United States economy. They contribute to the United States balance of trade, helping to maintain the value of the dollar and pay for imports. In particular, they help to offset the United States' massive seafood trade deficit.

What matters in this report are not the specific estimates of economic impacts for 2010, but their relative scale and distribution. Future economic impacts of the Bristol Bay salmon industry will vary from year to year with catches and prices, but will remain similar in relative scale and distribution among states and stages of the distribution chain to those we estimated in this report.

The economic importance of the Bristol Bay salmon industry goes beyond the economic impacts and contributions which we estimated for this report. The Bristol Bay salmon industry is a major part of the broader Alaska and Pacific Northwest seafood industry, and pays for an important share of the fixed costs of many fishing and processing operations. Without the Bristol Bay salmon industry, fixed costs would be higher and profits lower in the rest of the seafood industry. The Bristol Bay salmon industry is a major supporter of infrastructure and utilities in the Bristol Bay region, a major taxpayer, and a very important source of local jobs and income.

Figure VIII-1

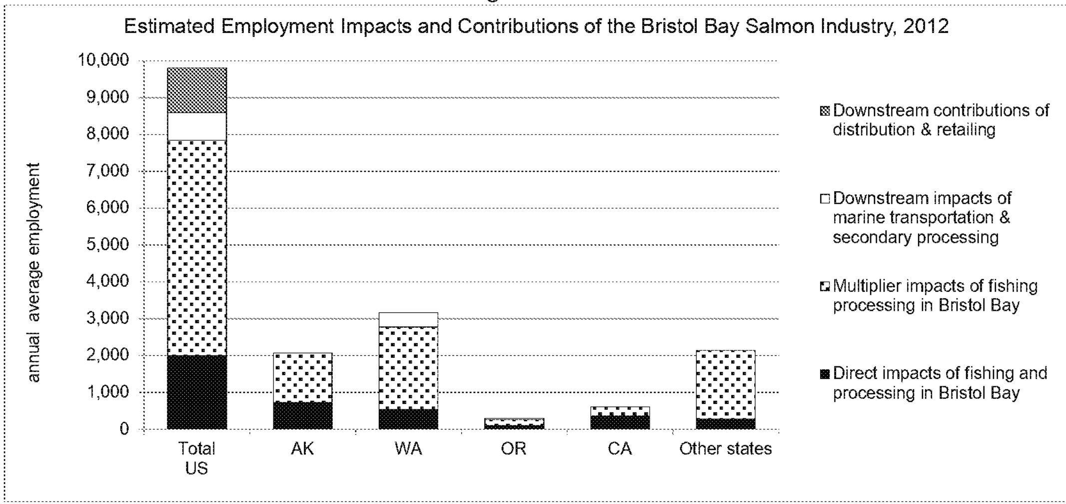


Figure VIII-2

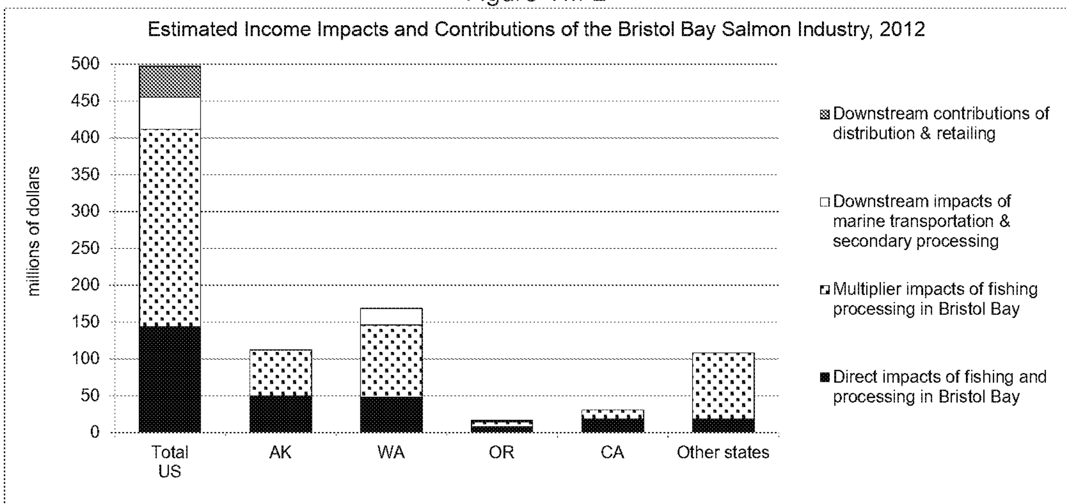


Figure VIII-3

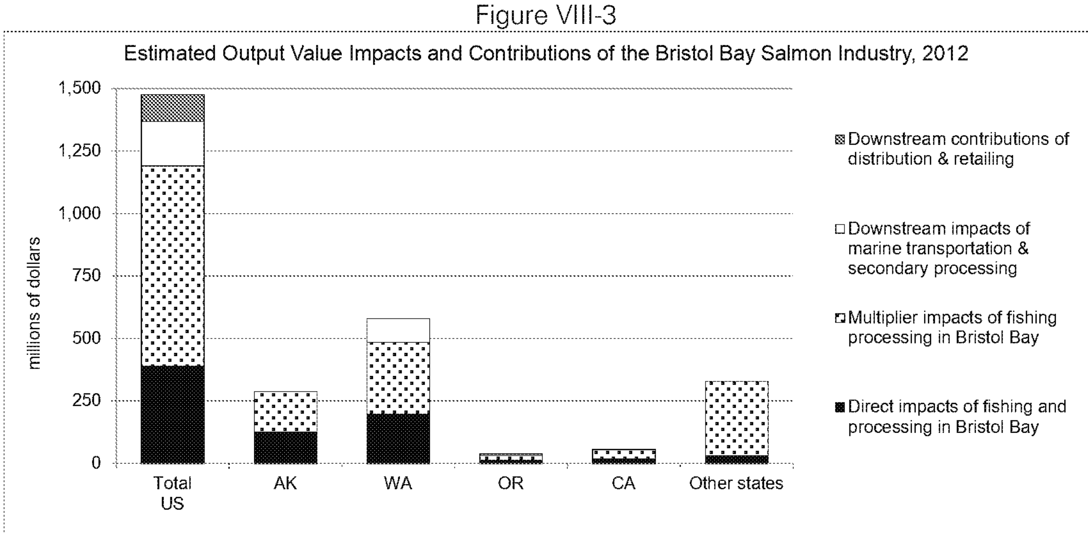


Table VIII-1

Estimated Employment Impacts and Contributions of the Bristol Bay Salmon Industry, 2010 (annual average employment)

Impact Driver		Total US	AK	WA	OR	CA	Other states
Fishing and primary processing in Bristol Bay	Direct impacts*	1,987	728	538	92	357	271
	Multiplier impacts	5,852	1,338	2,237	163	249	1,865
	Total impacts	**7,839**	**2,067**	**2,775**	**255**	**606**	**2,137**
Marine transportation & secondary processing	Direct impacts	191		156	15		
	Multiplier impacts	563		229	24		
	Total impacts	**754**		**385**	**39**		
Total impacts		**8,592**		**3,160**	**294**		
Nationwide distribution and retailing	Direct contributions	787					
	Multiplier contributions	425					
	Total contributions	**1,212**					
Total impacts & contributions		**9,804**					

Table VIII-2

Estimated Income Impacts and Contributions of the Bristol Bay Salmon Industry, 2010 (millions of dollars)

Impact Driver		US	AK	WA	OR	CA	Other states
Fishing and primary processing in Bristol Bay	Direct impacts	144	50	48	8	19	18
	Multiplier impacts	268	62	98	7	12	90
	Total impacts	**412**	**112**	**146**	**15**	**31**	**108**
Marine transportation & secondary processing	Direct impacts	13		11	1		
	Multiplier impacts	30		12	1		
	Total impacts	**43**		**23**	**2**		
Total impacts		**455**		**169**	**17**		
Nationwide distribution and retailing	Direct contributions	23					
	Multiplier contributions	20					
	Total contributions	**42**					
Total impacts & contributions		**497**					

Table VIII-3

Estimated Output Value Impacts and Contributions of the Bristol Bay Salmon Industry, 2010 (millions of dollars)

Impact Driver		US	AK	WA	OR	CA	Other states
Fishing and primary processing in Bristol Bay	Direct impacts	390	127	198	13	19	32
	Multiplier impacts	801	161	288	19	37	297
	Total impacts	**1,191**	**288**	**486**	**32**	**56**	**329**
Marine transportation & secondary processing	Direct impacts	68		56	4		
	Multiplier impacts	111		37	3		
	Total impacts	**179**		**93**	**6**		
Total impacts		**1,370**		**580**	**38**		
Nationwide distribution and retailing	Direct contributions	46					
	Multiplier contributions	61					
	Total contributions	**106**					
Total impacts & contributions		**1,476**					

APPENDIX A:
ESTIMATION OF DIRECT ECONOMIC IMPACTS OF BRISTOL BAY SALMON FISHING AND PROCESSING

The direct economic impacts of Bristol Bay salmon fishing and processing are the employment, income and output value created in Bristol Bay every summer in the fishing and processing industries. Table A-1 summarizes our estimates of these direct economic impacts. This appendix discusses how we developed these estimates.

Table A-1

Estimated Direct Economic Impacts of Bristol Bay Salmon Fishing and Processing, 2010

	Total US	AK	WA	OR	CA	Other states
Seasonal employment	11,921	4,369	3,227	553	2,143	1,629
Annual average employment	1,987	728	538	92	357	271
Income ($ million)	143.7	50.1	48.2	8.1	18.9	18.4
Output value ($ million)	389.7	126.7	198.5	13.4	19.4	31.7

Sources: See discussion in Appendix A. Note: Direct employment and income impacts are allocated to the states in which workers are residents; direct output value impacts are allocated to the states to which payments from total output value are made (including wage payments).

Challenges in Measuring Bristol Bay Salmon Industry Employment

Measuring employment in the Bristol Bay salmon industry is complicated by several factors. First, no employment data are collected for commercial fishing comparable to the employment data collected for most other industries. This is because commercial fishermen (both permit holders and crew) are considered self-employed, and they do not pay unemployment insurance. Employment data for most industries (including fish processing) are based on unemployment insurance reporting forms filed by employers. To make up for this significant gap in Alaska employment data, the Alaska Department of Labor and Workforce Development (ADLWD) Research and Analysis Division estimates monthly commercial fishing employment by multiplying the number of permits for which fish landings are reported each month by assumed average employment per permit fished (crew factors).

Second, the Bristol Bay salmon industry is highly seasonal. Most of the fishing and processing occurs between the middle of June and the middle of July, with smaller numbers of fishermen and processing workers engaged in smaller-scale fishing and processing as well as start-up and close-down activities earlier and later in the year. Thus a Bristol Bay fishing or processing job which typically lasts about two months is not directly comparable to a year-round job in another industry. To provide a basis for comparing employment in the Bristol Bay salmon industry with year-round employment in other industries, we estimate "annual average employment," calculated as the total number of months worked divided by 12.

Third, the "Bristol Bay Region" for which ADLWD reports fish processing employment and estimated salmon fishing employment includes the Chignik salmon fishery—an important Alaska salmon fishery although much smaller than the Bristol Bay fishery. By way of comparison, between 2006 and 2010, expressed as a percentage of the Bristol Bay salmon fisheries, total pounds landed in the Chignik salmon fishery were 7.7% of Bristol Bay, earnings were 6.3% of Bristol Bay, and total permits fished were 2.4% of Bristol Bay. Thus ADLWD fish harvesting and processing employment estimates and data for the "Bristol Bay region" slightly overestimate employment for the Bristol Bay salmon fishery.

Fourth, estimates of fish processing employment are not available by fishery—because in reporting employment fish processing plants do not distinguish between the species of fish that their workers were processing during the reporting period. Thus fish processing employment estimates for the Bristol Bay region include some employment in processing other species such as herring. However, it is likely that fish processing employment data for the Bristol Bay region are overwhelmingly dominated by Bristol Bay salmon. For a comparison of the relative scale of the two fisheries, between 2006 and 2010, expressed as a percentage of the Bristol Bay salmon fisheries, total pounds landed in the Bristol Bay (Togiak) herring seine and gillnet fisheries were 22.6% of pounds landed in the Bristol Bay salmon fisheries, earnings were 2.1% of earnings in the salmon fisheries, and the total permits fished were 2.6% of permits fished in the salmon fisheries (CFEC Basic Information Tables). Note also that Bristol Bay herring processing is much less labor intensive than salmon processing because Bristol Bay herring are entirely frozen round for export.

Estimation of Direct Employment Impacts

The direct employment impacts of Bristol Bay salmon and fishing are the seasonal jobs created every summer in Bristol Bay. The starting point for our estimates of direct employment impacts were the data shown in Tables A-2 and A-3 below. Table A-2 shows Alaska Department of Labor and Workforce Development (ADLWD) estimates of Bristol Bay salmon harvesting and processing employment and wages in 2010. Note that the harvesting employment estimate of 7035 is are for the peak harvesting employment month of July (by way of comparison, estimated 2010 Bristol Bay salmon harvesting employment was 6573 for June, 1065 for August, 68 for September, and 0 for all other months).

Table A-2

Alaska Department of Labor and Workforce Development Estimates of Bristol Bay Salmon Fishing and Processing Employment and Wages, 2010

Estimated salmon harvesting employment, July	7035
Bristol Bay region seafood processing total worker count	4886
Bristol Bay region seafood processing percent nonresident workers	87.0%
Bristol Bay region seafood processing wages	$33,963,492
Bristol Bay region percent nonresident wages	88.5%

Sources: ADLWD Bristol Bay Region Fishing Employment Estimates; ADLWD Bristol Bay Region Seafood Processing Employment and Earnings Data.

Table A-3 shows Commercial Fisheries Entry Commission (CFEC) 2010 data for Bristol Bay limited entry permit holders, pounds landed, and estimated gross earnings by state. These data are the basis for much of our estimation of economic impacts of Bristol Bay *fishing* by state. Note that while Alaska accounted for 53.1% of Bristol Bay permit holders, it accounted for only 41.8% of gross earnings—partly because Alaskans had lower average gross earnings in both fisheries, and partly because Alaskans accounted for a relatively higher share of permits in the set gillnet fishery, in which average earnings are lower than for the drift gillnet fishery. In contrast, Washington accounted for only 27.7% of permits but for 36.0% of gross earnings.

Table A-3

Bristol Bay Limited Entry Permit Holders, Pounds Landed, and Estimated Gross Earnings, by State, 2010

	Fishery	Total	Alaska	Washington	Oregon	California	Other
Number of permit holders	Drift	1,850	845	642	98	109	156
	Set	927	629	127	38	34	99
	Total	2,777	1,474	769	136	143	255
	% of total	100.0%	53.1%	27.7%	4.9%	5.1%	9.2%
Number of permits issued	Drift	1,863	854	644	98	110	157
	Set	982	665	135	39	37	106
	Total	2,845	1,519	779	137	147	263
	% of total	100.0%	53.4%	27.4%	4.8%	5.2%	9.2%
Number of fishermen who fished	Drift	1,510	660	538	87	87	138
	Set	816	535	118	39	32	92
	Total	2,326	1,195	656	126	119	230
	% of total	100.0%	51.4%	28.2%	5.4%	5.1%	9.9%
Number of permits fished	Drift	1,494	650	538	87	87	138
	Set	861	566	124	40	35	100
	Total	2,355	1,216	662	127	122	238
	% of total	100.0%	51.6%	28.1%	5.4%	5.2%	10.1%
Total pounds landed	Drift	147,221,522	54,965,123	60,545,242	9,039,937	8,624,445	14,046,775
	Set	34,004,833	21,551,668	4,504,097	1,779,431	1,548,168	4,621,469
	Total	181,226,355	76,516,791	65,049,339	10,819,368	10,172,613	18,668,244
	% of total	100.0%	42.2%	35.9%	6.0%	5.6%	10.3%
Estimated gross earnings	Drift	$134,136,756	$49,465,892	$55,341,651	$8,383,182	$8,058,292	$12,887,739
	Set	$31,022,079	$19,527,908	$4,178,869	$1,617,831	$1,448,873	$4,248,599
	Total	$165,158,835	$68,993,800	$59,520,520	$10,001,013	$9,507,165	$17,136,338
	% of total	100.0%	41.8%	36.0%	6.1%	5.8%	10.4%
Average gross earnings per permit fished	Drift	$89,784	$76,101	$102,866	$96,358	$92,624	$93,389
	Set	$36,030	$34,502	$33,701	$40,446	$41,396	$42,486
	Total	$70,131	$56,738	$89,910	$78,748	$77,928	$72,001

Source: CFEC Permit and Fishing Activity Data.

Table A-4 shows how we estimated seasonal and annual average employment in Bristol Bay salmon *fishing* in 2010. We started with the ADLWD estimate of 7035 for seasonal employment, and allocated this among states based on the distribution of limited entry permits. In doing this, we in effect assumed that fishing crew live in the same states as permit holders, and that the average number of crew per fishing operation is the same across states. Although neither of these assumptions is completely accurate, we had no other data with which to develop a better way of allocating crew among states.

As also discussed in Appendix B, in November 2012 we conducted a short online survey of 21 Washington residents who held Bristol Bay permits (20 drift gillnet permits and 1 set gillnet permit) about their fishing operations, primarily to learn more about their expenditures associated with the fishery. Of these, 13 responded that all of their crew were from Washington, and another 5 responded that some of their crew were from Washington. This suggests that most though not all Bristol Bay crew are likely to be from the same states as the permit holders with whom they fish. Moreover, to the extent that they are not, California residents hired as crew by Washington residents may be partially "balanced" by Washington residents hired as crew by California residents—and so forth for other states considered in our study.

Table A-4

Estimated Employment in Bristol Bay Salmon Fishing, 2010

	Sources & notes	Total	AK	WA	OR	CA	Other states
Assumed total seasonal fishing employment	a	7035					
Assumed share of fishing employment, by state	b	100.0%	53.1%	27.7%	4.9%	5.1%	9.2%
Assumed seasonal fishing employment, by state	c	7035	3734	1948	345	362	646
Assumed annual average fishing employment, by state	d	1173	622	325	57	60	108

(a) Estimated salmon harvesting employment, July, from Table IV-2.

(b) Share of total permit holders, by state, from Table IV-3.

(c) Calculated by multiplying assumed total seasonal employment by the assumed share of fishing employment by state.

(d) Calculated by dividing assumed seasonal employment by 6, based on the assumption that Bristol Bay seasonal fishing jobs represent 2 months employment on average.

Table A-5

Responses of Washington residents who hold Bristol Bay permits to the question "What state did the people who worked for you live in?"

State(s)	Number of responses
Washington	13
Washington & California	2
Washington & Alaska	1
Washington & Utah	1
Washington, Alaska & New Mexico	1
Oregon & Alaska	1
Texas & Colorado	1
Maine	1
Total	**21**

Source: November 2012 survey of Washington permit holders. See discussion in Appendix B.

Table A-6 shows how we estimated seasonal and annual average employment in Bristol Bay salmon *processing* in 2010. We begin with the ADLWD figure for the Bristol Bay region 2010 seafood processing worker total count of 4866, which we assume as a measure of total 2010 seasonal employment in Bristol Bay salmon seafood processing. The same data source reports that 87% of these workers were non-Alaska residents, which implies that 4251workers were non-Alaska residents and 635 were Alaska residents.

ADLWD did not report what states the non-resident workers lived in. To estimate this, we used unpublished data provided to us by ADLWD for Alaska unemployment payments to non-resident manufacturing workers (most of whom work in fish processing) to calculate the percentage of these unemployment insurance payments received by residents of Washington, Oregon, California, and other states. We assumed—in the absence of an alternative better approach—that Bristol Bay nonresident processing employment was distributed in the same proportions.

Table A-6

Estimated Employment in Bristol Bay Salmon Processing, 2010

	Notes	Total	AK	WA	OR	CA	Other states	Total Non-Alaska
Bristol Bay region seafood processing total worker count	a	4886						
Percent of Bristol Bay region seafood processing workers, by residency	a	100.0%	13.0%					87.0%
Assumed Alaska and non-Alaska worker count	b		635					4251
Alaska unemployment payments to manufacturing workers, 2010, by state to which payments were sent	c			$8,198,281	$1,334,785	$11,411,708	$6,298,954	$27,243,728
Share of non-Alaska unemployment payments	d			30.1%	4.9%	41.9%	23.1%	100.0%
Assumed non-Alaska worker count by state	e			1279	208	1781	983	4251
Assumed seasonal employment in Bristol Bay processing	f	4886	635	1279	208	1781	983	
Assumed annual average employment in Bristol Bay processing	g	**814**	**106**	**213**	**35**	**297**	**164**	

(a) Source: ADLWD Bristol Bay Region Seafood Processing Employment and Earnings Data; (b) Calculated from (a); (c) Source: Unpublished data provided by Alaska Department of Labor and Workforce Development, Research and Analysis Section, for payments to workers in NAICS code 31 (Manufacturing) which is dominated in Alaska by fish processing; (d) Calculated from (c); ((d) Calculated from percentages of workers by residency; (e) Assumed based on (d): assumes that Bristol Bay non-Alaska processing employment and processing wages were distributed geographically in the same proportion as statewide non-Alaska manufacturing unemployment insurance payments; (f) Values calculated in rows above; (g) Calculated by dividing estimated seasonal employment by 6, based on the assumption that Bristol Bay seasonal processing jobs represent 2 months employment, on average.

Note that this method of allocating non-resident processing employment assumed that all Bristol Bay processing workers lived in the United States. This was clearly not the case, given the fact that some of the workers were foreigners working in Alaska under the J-1 summer work travel visa program. In 2010, a total of 4383 workers in Alaska held J-1 summer work travel visas (http://j1visa.state.gov/basics/facts-and-figures/). Many but not all of these worked in the seafood processing industry: some worked in other industries such as tourism. This compares with a total worker count of 23,432 for the Alaska statewide seafood processing industry (http://laborstats.alaska.gov/seafood/statewide/AKSFPOver.pdf). If all J-1 visa holders had worked in the seafood industry, they would have represented 19% of the statewide processing workforce. Their share in the Bristol Bay processing workforce could have been the same, higher or lower. Had it been the same, actual employment of residents of states other than Alaska would have been about 81% of our estimates in Table A-6.

The J-1 summer work travel visa program is being phased out. Within a few years, it is likely that almost all Bristol Bay workers will be US residents.

Map in a Bristol Bay processor's cafeteria with pins showing where the workers were from

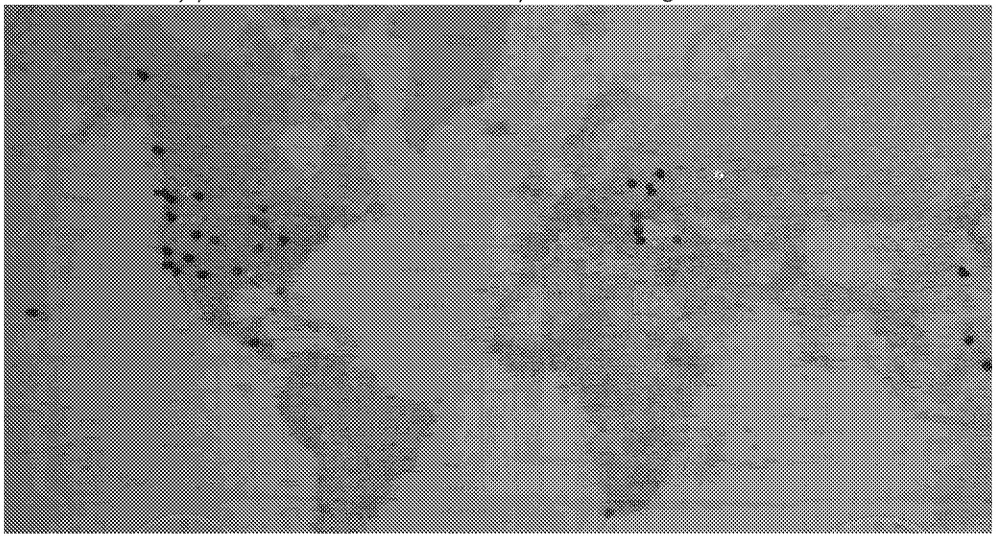


Table A-7 summarizes our estimates of seasonal employment in Bristol Bay salmon and fishing derived in Tables A-5 and A-7. The totals, which correspond to the first line of Table A-1 at the beginning of this chapter, are the estimated direct seasonal employment impacts of Bristol Bay salmon fishing and processing in 2010.

Table A-7

Estimated Seasonal Employment in Bristol Bay Salmon Fishing & Processing, 2010

	Total	AK	WA	OR	CA	Other states
Fishing	7,035	3,734	1,948	345	362	646
Processing	4,886	635	1,279	208	1,781	983
Total	**11,921**	**4,369**	**3,227**	**553**	**2,143**	**1,629**

Sources: Estimates in Tables IV-5 (fishing) and IV-6 (processing).

Note: Estimates are by workers' state of residence.

Table A-8 shows our estimates of annual average employment in Bristol Bay fishing and processing. These estimates are simply the seasonal estimates shown in Table A-7 divided by 6—based on the assumption that each seasonal fishing and processing job in Bristol Bay represents, on average, the equivalent of two months of work. The totals, which correspond to the second line of Table A-1 at the beginning of this chapter, are the estimated direct annual average employment impacts of Bristol Bay salmon fishing and processing in 2010.

Table A-8

Estimated Annual Average Employment in Bristol Bay Salmon Fishing & Processing, 2010

	Total	AK	WA	OR	CA	Other states
Fishing	1,173	622	325	57	60	108
Processing	814	106	213	35	297	164
Total	**1,987**	**728**	**538**	**92**	**357**	**271**

Sources: Estimates in Tables IV-5 (fishing) and IV-6 (processing). Calculated by dividing assumed seasonal employment by 6, based on the assumption that Bristol Bay seasonal fishing jobs represent 2 months employment on average.

Note: Estimates are by workers' state of residence.

Estimation of Direct Income Impacts

The direct income impacts of Bristol Bay salmon and fishing are the income people earn from fishing and processing in Bristol Bay. As shown in Table A-9, we estimated three components of these direct income impacts: the income earned by fishing crew, the income of permit holders (after subtracting their operating expenses from their gross income), and the income of processing workers.

Table A-9

Estimated Direct Income Impacts of Bristol Bay Salmon Fishing and Processing, 2010

	Total	AK	WA	OR	CA	Other states
Payments to fishing crew (a)	$37,074,363	$15,451,313	$13,399,581	$2,246,435	$2,135,997	$3,841,037
Permit holder income net of operating expenses (a)	$72,668,608	$30,760,455	$25,758,280	$4,384,347	$4,162,374	$7,603,152
Processor payments to processing workers (b)	$33,963,492	$3,905,802	$9,045,069	$1,472,653	$12,590,406	$6,949,563
Total	**$143,706,463**	**$50,117,570**	**$48,202,930**	**$8,103,434**	**$18,888,777**	**$18,393,752**

Note: Estimates are by state of residence of income recipients.
(a) Source: Appendix B, Table B-5.
(b) Source: Table A-8.

We discuss our estimates of the income of fishing crew and permit holders in Appendix B. Table A-10 shows how we estimated wage earnings of processing workers, starting with total Bristol Bay processing wage earnings reported by the Alaska Department of Labor and Workforce Development, and allocating these by states based on the geographic distribution of unemployment insurance payments, in the same way as we estimated the geographic distribution of processing employment in Table A-6.

Table A-10

Estimated Wage Earnings in Bristol Bay Salmon Processing, 2010

	Notes	Total	AK	WA	OR	CA	Other states	Total Non-Alaska
Alaska unemployment payments to manufacturing workers, 2010, by state to which payments were sent	a	$41,585,887	$14,342,159	$8,198,281	$1,334,785	$11,411,708	$6,298,954	$27,243,728
Share of non-Alaska unemployment payments	b			30.1%	4.9%	41.9%	23.1%	100.0%
Total Bristol Bay processing industry wage payments	c	$33,963,492						
Percent of Bristol Bay processing wage payments, by residency	c	100.0%	11.5%					88.5%
Bristol Bay processing industry wage payments, by residency	h		$3,905,802					$30,057,690
Assumed non-Alaska wage payments, by state	e			$9,045,069	$1,472,653	$12,590,406	$6,949,563	
Assumed Bristol Bay payments to processing workers, by state	f	**$33,963,492**	**$3,905,802**	**$9,045,069**	**$1,472,653**	**$12,590,406**	**$6,949,563**	

Sources and notes: (a) Source: Unpublished data provided by Alaska Department of Labor and Workforce Development, Research and Analysis Section, for payments to workers in NAICS code 31 (Manufacturing) which is dominated in Alaska by fish processing; (b) Calculated from (a); (c) Source: ADLWD Bristol Bay Region Seafood Processing Employment and Earnings Data; (d) Calculated from percentages of workers by residency; (e) Assumed based on (b): assumes that Bristol Bay non-Alaska processing employment and processing wages were distributed geographically in the same proportion as statewide non-Alaska unemployment insurance payments; (f) Values calculated in rows above; (g) Calculated by dividing estimated seasonal employment by 6, based on the assumption that Bristol Bay seasonal processing jobs represent 2 months employment, on average; (h) Calculated from percentages of wage payments by residency.

Estimation of Direct Output Value Impacts

The output value of Bristol Bay salmon fishing and processing includes the output value created in fishing (the ex-vessel value paid to fishermen) and the additional value increases in primary processing (the total first wholesale value of Bristol Bay production minus the ex-vessel value).

Ex-Vessel Value of Bristol Bay Salmon Harvests

The ex-vessel value of Bristol Bay salmon harvests is the total amount paid to Bristol Bay permit holders by processors; it is equivalent to *permit holders gross earnings*. Two sources of data are available for ex-vessel value:

- *CFEC data:* Data published by the Alaska Commercial Fisheries Entry Commission (CFEC) in several places on the CFEC website at www.cfec.state.ak.us. The data distinguish between the ex-vessel value of harvests in the drift gillnet and set gillnet fisheries, but do not distinguish between ex-vessel value by species.

- *ADF&G data*: Data published by the Alaska Department of Fish and Game (ADF&G) on the ADF&G website in annual "Alaska Commercial Salmon Harvests and Ex-Vessel Values" tables at http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmoncatch. The data distinguish between the value of harvests by species, but do not distinguish between the value of harvests in the drift gillnet and set gillnet fisheries.

As shown in Table A-11, these two data sources provide different estimates of the total value of the Bristol Bay salmon harvest. In most years the estimates are fairly close, but in 2010—the year for which we prepared our economic impacts—they differed significantly, by $20 million. It is not clear why they differ, or which estimate is more accurate. In this report, for our analysis of economic impacts, we used the lower CFEC estimate of $165 million (shown in the shaded cell of the table) as our assumption for the 2010 ex-vessel value, because we were also relying on CFEC data for our assumptions about the distribution of permit holders and permit holder earnings by state. In Chapter II, for our discussion of trends over time in Bristol Bay sockeye salmon prices and value (Figure II-4) and our discussion of the relative share of Bristol Bay sockeye salmon in Alaska and world salmon harvest value (Table II-3) we used ADF&G data because they are specific to sockeye salmon.

Table A-11

CFEC & ADF&G Estimates of the Ex-Vessel Value of the Bristol Bay Salmon Harvest

Data source	Species or fishery	2008	2009	2010	2011
CFEC data	Drift gillnet fishery	$100,139,700	$122,005,800	$134,136,756	$131,544,714
	Set gillnet fishery	$20,955,694	$26,211,898	$31,022,079	$27,365,503
	Total	**$121,095,394**	**$148,217,698**	**$165,158,835**	**$158,910,217**
ADFG Data	Sockeye salmon	$116,717,000	$144,200,000	$180,818,000	$158,383,000
	Other species	$2,221,000	$2,075,000	$4,210,000	$2,107,000
	Total	**$118,938,000**	**$146,275,000**	**$185,028,000**	**$160,490,000**

Sources: CFEC Basic Information Tables and CFEC Permit and Fishing Activity Data; ADF&G Alaska Commercial Salmon Harvests and Ex-vessel Values Reports.

Increase in Value in Primary Processing

The increase in value in primary processing of Bristol Bay salmon is the total first wholesale value minus the ex-vessel value. Reliable data on first wholesale value are available from the Commercial Operator Annual Reports filed every year by processors, in which they report their total production and total first wholesale value (FOB Bristol Bay) by product and species. The total first wholesale value of Bristol Bay production in 2010 was $389,667,996 (the shaded cell in Table A-12). This is one of the most important numbers reported in this study. It clearly shows that the total direct output value impact of Bristol Bay salmon fishing and processing in 2010 was very large—measured in the hundreds of millions of dollars.

As will be apparent from Appendixes B and D, estimating the multiplier impacts of Bristol Bay fishing and processing required us to make numerous "best judgment" assumptions, based on discussions with industry sources and our own knowledge of the industry, about how payments from first wholesale value are allocated across industries and states. The uncertainty associated with these assumptions imparts uncertainty to our estimates of multiplier impacts. However, regardless of how payments from first wholesale value are allocated by industry or among states, the scale of direct output value impacts means that the national multiplier impacts of Bristol Bay salmon and processing were also very large.

Table A-12

Volume, First Wholesale Value and Average First Wholesale Price of Bristol Bay Salmon Primary Production, 2010

	Total	Frozen	Canned	Fresh	Roe
Volume (pounds)	116,718,352	79,961,576	29,895,751	2,899,396	3,961,628
Value ($)	**$389,667,996**	$258,255,152	$105,376,086	$6,119,811	$19,916,948
Average price ($/lb)		$3.23	$3.52	$2.11	$5.03

Source: Alaska Department of Fish and Game, Commercial Operator Annual Reports database.
Note: Excludes small volumes and values of other products for which data were confidential.

Table A-13 summarizes our direct output value assumptions. The direct output value in processing is the difference between the total first wholesale value of $389,667,996 (from Table A-11) and total ex-vessel value of $165,158,835 (from Table A-10), or $224,509,160. Output value is allocated by the states to which payments from output value are made. For example, if a processor buys $1,000,000 of cans from a company in California, that portion of output value is allocated to California. If a permit holders pays $50,000 to a crew member from Washington, that portion of output value is allocated to Washington. We discuss our assumptions about the allocation of payments among states in detail in Appendix B.

Table A-13

Estimated Direct Output Value Impacts of Bristol Bay Salmon Fishing and Processing, 2010

	Total	AK	WA	OR	CA	Other states
Fishing	$165,158,836	$83,306,625	$55,577,935	$7,163,324	$6,807,849	$12,303,103
Processing	$224,509,160	$43,355,550	$142,913,670	$6,257,029	$12,590,406	$19,392,506
Total	$389,667,996	$126,662,175	$198,491,605	$13,420,353	$19,398,255	$31,695,609

Note: Impacts are allocated to the states to which payments are made.

Sources: See Table A-11 for discussion of total output value created in fishing (= total ex-vessel value). See Table A-12 for discussion of total direct output value (= total first wholesale value). Total direct output value in processing (= total value increase in processing) was calculated by substracting total ex-vessel value from total first wholesale value. See Appendix B, and particularly Tables B6 and B8, for discussion of the allocation of total ouput value (total payments) among states.

APPENDIX B:
ESTIMATION OF MULTIPLIER ECONOMIC IMPACTS OF BRISTOL BAY SALMON FISHING AND PROCESSING

The multiplier economic impacts of Bristol Bay salmon fishing and processing are the indirect and induced impacts on other industries driven by payments of fishermen and processors to businesses and households. In this appendix, we discuss our estimation of these impacts. We organize our discussion as follows:

- Estimation of permit holder payments by industry and state
- Estimation of processor payments by industry and state
- Estimation of multiplier impacts using IMPLAN models

Estimation of Permit Holder Payments by Industry and State

We estimated permit holder payments separately for each fishery based on surveys conducted by the Commercial Fisheries Entry Commission (CFEC) for the 2001 set gillnet fishery and by Northern Economics for the 2001 set gillnet fishery.

The CFEC survey was conducted in 2002 and received responses from 310 Bristol Bay drift gillnet permit holders (Schelle, 2002; Carlson, 2002). Subsequently, CFEC used the survey responses and other CFEC data to estimate nominal average gross earnings, costs and net returns of drift gillnet permit holders for the years 1983-2003 (Schelle et al, 2004). Table B-1 shows how we used these CFEC estimates of nominal costs for the years 1983-2003 to estimate total payments of the drift gillnet fishery by category in 2010.

Note that we could not simply adjust average 1983-2003 payments for inflation, because both catches and prices varied widely over this period and from 2010. For most payment categories, we assumed, based on our best judgment, either that average real expenditures remained constant, real expenditures per pound remained constant, the share of payments in total expenditures remained constant, or a weighted combination of these assumptions.[2]

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[2] As shown in footnote f of Table B-1, crew share was calculated as 22.55% of total earnings. This percentage was based on the average for the years 1983-2003 of the CFEC estimated crew payment as a percentage of total earnings minus estimated payments for food and fuel. To be exactly consistent with the CFEC estimates, our estimated crew payments for 2010 should have been 22.55% of total earnings minus estimated 2010 payments for food and fuel. This would have resulted in slightly lower estimates of $19,031 for average crew payments and $28,432,674 for total crew payments--and correspondingly higher estimates of average returns to labor, management and investment. However, this would not have made any difference in our economic impact calculations, because payments to crew and payments to permit holders (as average returns to labor, management and investment) are assumed to have the same economic impacts and to be allocated among states in the same way.

Table B-1

Derivation of Payment Assumptions for the Drift Gillnet Fishery

Payment category	CFEC estimates of average real costs per drift gillnet permit holder, 1983-2003, expressed in 2010 dollars (a)	2010 payment assumptions (b) Inflation-adjusted average CFEC cost (c)	Inflation-adjusted average CFEC cost per pound (d)	Share of CFEC costs (e)	Other (f)	Assumed payments per drift gillnet permit holder in 2010 (g)	Assumed total payments by drift gillnet permit holders in 2010 (h)
Food	$2,299	1				$2,299	$3,433,982
Fuel, oil and lubricants	$2,395	0.5	0.5			$3,089	$4,615,528
Crew payments	$21,824				1	$20,247	$30,249,506
Maintenance	$3,570	0.5	0.5			$4,305	$6,431,725
Nets	$3,010	0.5	0.5			$3,782	$5,651,033
Misc. gear & supplies	$1,884	0.5	0.5			$2,314	$3,457,811
Raw fish tax	$2,174			1		$2,213	$3,305,851
Transportation	$2,957	1				$2,957	$4,417,459
Moorage, gear, storage and haulout	$1,900	1				$1,900	$2,838,262
Insurance	$3,347	1				$3,347	$5,000,299
Administrative services	$973	1				$973	$1,454,133
Permit renewal fees	$586				1	$300	$448,200
Vessel license fees	$45	1				$45	$67,377
Property Tax	$466	1				$466	$696,336
Depreciation (= Replacement payments for vessels & gear) (i)	$3,078	1				$3,078	$4,598,642
Avg. Returns to Labor, Management, and Investment (= Retained by permit holders) (j)	$51,255					$38,468	$57,470,613
Average and total earnings	$101,763					$89,784	$134,136,756

(a) Calculated from K. Schelle, K.Iverson, N. Free-Sloan and S. Carlson, *Bristol Bay Salmon Drift Gillnet Fishery Optimum Number Report* (2004), Table 3.2a: *Bristol Bay Salmon Drift Gillnet Fishery, 1983-2003: Estimated (nominal $) Average Gross Earnings, Costs and Net Returns*. Annual payments converted to real (2010) dollars prior to averaging based on the United States Consumer Price Index.

(b) Relative weight given to four different methods of calculating assumed payments per permit holder in 2010, as described in notes (b)-(f).

(c) Assumes that 2010 average payments per permit holder were the same as average of CFEC estimated payments for 1983-2003, expressed in real (2010) dollars.

(d) Assumes that 2010 average payments per *pound* were the same as average of CFEC estimated payments *per pound* for 1983-2003, expressed in real (2010) dollars.

(e) Assumes that 2010 payments were the same share of gross earnings as average of CFEC estimated payments for 1983-2003, expressed in real (2010) dollars

(f) Assumes total crew share of 22.55% of gross earnings; average permit renewal fee is actual 2010 permit renewal fee.

(g) Weighted average of four alternative methods of calculating assumed average payments per permit holder in 2010.

(h) Calculated by multiplying average payments per permit holder in 2010 by the total number of permits fished in 2010 (1494).

(i) Depreciation was assumed to equal replacement payments for vessels and gear.

(j) Calculated as the residual after deducting all other payments from average and total earnings. Average returns to labor, management and investment were assumed to equal payments retained by permit holders.

The CFEC cost estimates included depreciation. For our analysis, we assumed that depreciation was equal to replacement expenditures for vessels and gear. Note that this assumption smooths out wide variation from year to year in actual replacement expenditures.[3]

[3] This variation is apparent from wide variation in the number of Bristol Bay drift gillnet boats in use in the fishery that were built in different years, which we estimated from the permit and vessel files posted on the CFEC website (http://www.cfec.state.ak.us/) by matching 2011 permit holders' vessel ADF&G numbers with the vessel file to get the year of construction of vessels. Of those 2011 permit holders whose permit file reported vessel ADF&G numbers, 223 had vessels built in 1980; 102 had vessels built in 1989, and 62 had vessels built in 1996. In dramatic contrast, only 2 had vessels built in 2001, only 1 had a vessel built in 2002, and none had a vessel built in 2003. Clearly, during the period 2001-2003, when economic conditions in the fishery were very poor, very little vessel

Note also that our assumption that replacement expenditures for vessels and gear equals depreciation does not account for new investment for upgrading (as opposed to simply replacing) vessels and gear, such as investment in larger boats or refrigeration capacity. Thus our analysis understates the economic impacts of the Bristol Bay fishery on the boat building and boat gear industries, which are based primarily in Washington State.

As a check on the reliability of our payment assumptions shown in Table B-1, in November 2012 we conducted a short online survey of 21 Washington residents who held Bristol Bay permits. Of these, 19 responded to questions about their costs in 2011. Note that our survey sample was not random and had higher average gross earnings ($101,292) than the average reported by CFEC ($85,315) for all drift permit holders in 2011 (CFEC Basic Information Tables). Thus, to the extent that higher-than-average-earning fishermen also have higher-than-average costs, we would expect responses of our survey respondents to be slightly higher than our average payment assumptions for the fishery as a whole. In general, this appears to have been the case. While our survey size was too small and non-representative to provide a reliable measure of average payments for the fishery as a whole, nothing in our survey results suggests that our average payment assumptions for the 2010 fishery, as derived in Table B-1, are unreasonable.

Table B-2

Comparison of Drift Gillnet Permit Holder Average Payment Assumptions with Survey Responses

	Assumed payments per drift gillnet permit holder in 2010 (a)	Survey Responses (b)		
Payment category		Minimum	Average	Maximum
Food	$2,299	$1,000	$2,213	$4,500
Fuel, oil and lubricants	$3,089	$1,580	$4,312	$8,000
Crew payments	$20,247	$12,000	$30,512	$77,500
Maintenance	$4,305	$1,200	$16,526	$85,000
Transportation	$2,957	$1,580	$4,312	$8,000
Insurance	$3,347	$1,000	$2,372	$5,000
Other expenses (c)	**$11,994**	**$0**	**$9,490**	**$27,500**
Nets	$3,782			
Misc. gear & supplies	$2,314			
Raw fish tax	$2,213			
Moorage, gear, storage and haulout	$1,900			
Administrative services	$973			
Permit renewal fees	$300			
Vessel license fees	$45			
Property Tax	$466			
Depreciation	$3,078			
Avg. Returns to Labor, Management, and Investment	$38,468			
Average and total earnings	$89,784	$75,000	$101,292	$180,000

(a) Table B-1.

(b) Responses of 19 Washington State drift gillnet permit holders to an informal survey about operating expenses during the 2011 salmon season.

(c) Excludes depreciation and average returns to labor, management and investment.

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replacement took place. As economic conditions in the fishery improved in recent years, so did the number of boats being built. Of 2011 permit holders, 6 had boats built in 2009, 15 had boats built in 2010, and 18 had boats built in 2011.

We based our estimates of 2010 payments from the set gillnet fishery on estimates of average payments per set net permit holder in 2001, based on the data shown in Table B-3. These data were reported in an analysis done by Northern Economics (NE) for a 2003 analysis of options for restructuring the Bristol Bay salmon fishery (Northern Economics, *Assessment of Wealth in the Status Quo Fishery*, 2003). NE estimated payments for permit holders from three geographic areas (local, other Alaska, and non-Alaska) and three revenue rankings (low, medium, and high), using data supplied by the Commercial Fisheries Entry Commission (CFEC) for the number of permits, catches and gross earnings for each permit group. Note that these should be considered very approximate estimates. As described by Northern Economics:

> "Costs were estimated by Northern Economics through a series of telephone interviews with set net operators. A total of 15 operators were interviewed in October 2001, and the results from those interviews along with a set of assumptions on the part of the analysts were used to estimate typical costs in the set net fishery. Because of the very limited sample from the set net fishery, the information in the estimates of net revenues and wealth carries additional uncertainty. It should also be noted that the limited sample precluded stratification by residence and average catch. None-the-less, adjustments for residence and catch size were developed by the analysts based on their experience and judgment."

Table B-3

Northern Economics' Estimates of Average Earnings and Payments per Permit Holder in the Bristol Bay Set Gilnet Fishery, by Class, 2001, and Estimation of Average Payments per Permit Holder

	Local permit holders			Other Alaska permit holders			Non-Alaska permit holders			Estimated total, all classes combined	Estimated average payments per permit holder
Item	LR-Low	LR-Med	LR-High	OA-Low	Med.	OA-High	NA-Low	Med.	NA-High	(a)	(b)
Number of permits	78	124	143	56	94	112	53	95	87	842	
Total catch per permit (lbs)	$8,604	$21,929	$40,662	$8,553	$19,948	$37,788	$6,274	$18,191	$33,904	20,801,625	
Gross earnings per permit	$3,498	$8,798	$16,450	$3,501	$8,229	$15,476	$2,597	$7,553	$13,984	$8,490,824	$10,084
Payments per permit											
Crew payments	$166	$418	$782	$167	$391	$736	$123	$359	$665	$403,623	$479
Transportation	$0	$0	$0	$500	$500	$500	$1,000	$1,000	$1,000	$366,000	$435
Food	$575	$619	$683	$575	$614	$675	$567	$609	$663	$530,378	$630
Fuel, oil and lubricants	$126	$318	$595	$127	$297	$559	$94	$273	$506	$306,922	$365
Maintenance	$675	$817	$1,022	$675	$801	$996	$650	$783	$956	$716,757	$851
Nets	$461	$558	$699	$461	$548	$681	$445	$536	$654	$490,110	$582
Misc. gear & supplies	$879	$1,065	$1,332	$879	$1,045	$1,298	$848	$1,021	$1,246	$934,269	$1,110
Insurance	$161	$173	$191	$161	$172	$189	$159	$170	$185	$148,347	$176
Moorage, gear, storage and haulout	$105	$157	$232	$105	$152	$223	$96	$145	$208	$142,937	$170
Raw fish tax	$175	$440	$822	$175	$411	$774	$130	$378	$699	$424,491	$504
Vessel license fees	$100	$100	$100	$100	$100	$100	$100	$100	$100	$84,200	$100
Permit renewal fees	$312	$312	$312	$312	$312	$312	$312	$312	$312	$262,704	$312
Administrative services	$65	$165	$308	$66	$154	$290	$49	$141	$262	$159,012	$189
Fixed costs	$2,765	$3,278	$4,019	$3,265	$3,723	$4,425	$3,678	$4,158	$4,780	$3,231,065	$3,837
Variable costs	$1,036	$1,864	$3,060	$1,036	$1,775	$2,908	$895	$1,669	$2,674	$1,738,714	$2,065
Total costs	$3,801	$5,142	$7,079	$4,301	$5,498	$7,332	$4,573	$5,827	$7,455	$4,969,754	$5,902
Net returns	-$302	$3,656	$9,371	-$800	$2,731	$8,144	-$1,975	$1,726	$6,530	$3,521,288	$4,182

Source: Northern Economics, *Assessment of Wealth in the Status Quo Fishery* (2003), Table 21.

(a) Total payments estimated by multiplying average payments per permit by the number of permits for each class, and summing across classes.

(b) Average payments per permit holder estimated by dividing total payments by the total number of set net permit holders.

Table B-4 shows how we estimated 2010 payments based on the NE estimates of average payments per permit holder in 2001. We could not simply adjust all 2001 payments for inflation, because both catches and prices were significantly higher in 2010 than in 2001. For most payment categories, we assumed either that real expenditures remained constant, real expenditures per pound remained constant, the share of payments in total expenditures remained constant, or a weighted combination of these assumptions.

Table B-4

Derivation of Payment Assumptions for the Set-Net Fishery

			Weighting of methodologies used to develop 2010 payment assumptions (c)					
Payment category	Estimated average payments per permit holder in 2001 (a)	Estimated average payments per permit holder in 2001, expressed in 2010 dollars (b)	Inflation-adjusted average 2001 payment (d)	Inflation-adjusted average 2001 payment per pound (e)	Share of 2001 payments (f)	Other (g)	Assumed payments per permit holder in 2010 (h)	Assumed total payments by set-net permit holders in 2010 (i)
Food	$630	$776	1				$776	$667,769
Fuel, oil and lubricants	$365	$449	0.5	0.5			$580	$499,151
Crew payments	$479	$590				1	$7,927	$6,824,857
Maintenance	$851	$1,048	0.5	0.5			$1,354	$1,165,671
Nets	$582	$717	0.5	0.5			$926	$797,072
Misc. gear & supplies	$1,110	$1,366	0.5	0.5			$1,765	$1,519,413
Raw fish tax	$504	$621			1		$1,784	$1,536,135
Transportation	$435	$535	1				$535	$460,810
Moorage, gear, storage and haulout	$170	$209	1				$209	$179,964
Insurance	$176	$217	1				$217	$186,775
Administrative services	$189	$233	1				$233	$200,203
Permit renewal fees	$312	$384	1				$150	$129,150
Vessel license fees	$100	$123	1				$123	$106,011
Property Tax			1				$0	$0
Depreciation (= Replacement payments for vessels & gear) (j)						1	$1,802	$1,551,104
Avg. Returns to Labor, Management, and Investment (= Retained by permit holders) (k)	$4,279	$5,268					$17,652	$15,197,995

(a) Source: Table B-3. Estimated from data in Northern Economics, *Assessment of Wealth in the Status Quo Fishery* (2003), Table 21.

(b) Estimated by multiplying 2001 estimates by the ratio of the US CPI in 2010 to the ratio of the US CPI in 2001 (218.056/177.1 = 1.231).

(c) Relative weight given to four different methods of calculating assumed payments per permit holder in 2010, as described in notes (d)-(g).

(d) Assumes that average payments per permit holder were the same as in 2001, after adjusting for inflation.

(e) Assumes that average payments *per pound* were the same as in 2001, after adjusting for inflation.

(f) Assumes that payments were the same share of gross earnings as in 2001.

(g) Assumes crew shares of 10% of earnings per crew for an average of 2.2 crew per permit holder (= 22% of average earnings of $36,030 per permit holder or 22% of total earnings of $31,022,079); assumes depreciation of 5% of average and gross earnings.

(h) Weighted average of four alternative methods of calculating assumed average payments per permit holder in 2010.

(i) Calculated by multiplying average payments per permit holder in 2010 by the total number of permits fished in 2010 (861).

(j) Depreciation was assumed to equal replacement payments for vessels and gear.

(k) Calculated as the residual after deducting all other payments from average and total earnings. Average returns to labor, management and investment were assumed to equal payments retained by permit holders.

Table B-5 shows our combined payment assumptions for both the drift gillnet and set gillnet fishery, by the *state of residency of the permit holders*. The "Total" column of Table B-5 combines our total payment assumptions for the drift gillnet fishery (from Table B-1) and the set gillnet fishery (from Table B-4). The gross earnings rows of the table are CFEC data reported in Table A-3. We assumed that the share of residents of each state in each type of payment is proportional to their share of earnings. For example, since Washington residents accounted for 41.3% of gross earnings in the drift gillnet fishery, we assume that they also accounted for 41.3% of food payments, fuel payments, and so forth.[4]

Table B-5

Assumed Total Expenditures of Permit Holders, by Residency of Permit Holders

		Total	Alaska	Washington	Oregon	California	Other States
Drift gillnet fishery	**Gross Earnings**	**$134,136,756**	**$49,465,892**	**$55,341,651**	**$8,383,182**	**$8,058,292**	**$12,887,739**
	Food	$3,433,982	$1,266,357	$1,416,780	$214,615	$206,297	$329,934
	Fuel, oil, & lubricants	$4,615,528	$1,702,078	$1,904,258	$288,458	$277,279	$443,456
	Crew shares (excluding skipper)	$30,249,506	$11,155,174	$12,480,230	$1,890,512	$1,817,245	$2,906,345
	Maintenance (routine & unexpected)	$6,431,725	$2,371,841	$2,653,577	$401,965	$386,387	$617,954
	Nets (hanging, repair, and web)	$5,651,033	$2,083,943	$2,331,483	$353,174	$339,487	$542,946
	Miscellaneous gear & supplies	$3,457,811	$1,275,144	$1,426,611	$216,104	$207,729	$332,223
	Raw fish tax	$3,305,851	$1,219,105	$1,363,916	$206,607	$198,600	$317,623
	Transportation	$4,417,459	$1,629,036	$1,822,539	$276,079	$265,380	$424,426
	Moorage, storage, and haul-out	$2,838,262	$1,046,672	$1,171,000	$177,384	$170,509	$272,698
	Insurance (P&I, hull, lay-up)	$5,000,299	$1,843,971	$2,063,005	$312,505	$300,394	$480,424
	Administrative services	$1,454,133	$536,244	$599,941	$90,879	$87,357	$139,712
	Annual permit fee	$448,200	$165,284	$184,917	$28,011	$26,926	$43,063
	Annual vessel license fee	$67,377	$24,847	$27,798	$4,211	$4,048	$6,473
	Property Tax	$696,336	$256,789	$287,292	$43,519	$41,833	$66,903
	Vessel and gear replacement	$4,598,642	$1,695,851	$1,897,291	$287,403	$276,264	$441,833
	Retained by permit holders	$57,470,613	$21,193,558	$23,711,015	$3,591,757	$3,452,558	$5,521,725
Set gillnet fishery	**Gross Earnings**	**$31,022,079**	**$19,527,908**	**$4,178,869**	**$1,617,831**	**$1,448,873**	**$4,248,599**
	Food	$667,769	$420,350	$89,953	$34,825	$31,188	$91,454
	Fuel, oil, & lubricants	$499,151	$314,208	$67,239	$26,031	$23,313	$68,361
	Crew shares (excluding skipper)	$6,824,857	$4,296,140	$919,351	$355,923	$318,752	$934,692
	Maintenance (routine & unexpected)	$1,165,671	$733,771	$157,023	$60,791	$54,442	$159,643
	Nets (hanging, repair, and web)	$797,072	$501,744	$107,371	$41,568	$37,227	$109,162
	Miscellaneous gear & supplies	$1,519,413	$956,446	$204,674	$79,239	$70,964	$208,090
	Raw fish tax	$1,536,135	$966,972	$206,927	$80,111	$71,745	$210,380
	Transportation	$460,810	$290,072	$62,074	$24,032	$21,522	$63,110
	Moorage, storage, and haul-out	$179,964	$113,284	$24,242	$9,385	$8,405	$24,647
	Insurance (P&I, hull, lay-up)	$186,775	$117,572	$25,160	$9,741	$8,723	$25,580
	Administrative services	$200,203	$126,025	$26,969	$10,441	$9,350	$27,419
	Annual permit fee	$129,150	$81,298	$17,397	$6,735	$6,032	$17,688
	Annual vessel license fee	$106,011	$66,733	$14,280	$5,529	$4,951	$14,519
	Property Tax	$0	$0	$0	$0	$0	$0
	Vessel and gear replacement	$1,551,104	$976,395	$208,943	$80,892	$72,444	$212,430
	Retained by permit holders	$15,197,995	$9,566,897	$2,047,265	$792,590	$709,816	$2,081,427
Total: drift gillnet and set gillnet fisheries	**Gross Earnings**	**$165,158,835**	**$68,993,800**	**$59,520,520**	**$10,001,013**	**$9,507,165**	**$17,136,338**
	Food	$4,101,750	$1,686,706	$1,506,732	$249,439	$237,485	$421,387
	Fuel, oil, & lubricants	$5,114,679	$2,016,286	$1,971,496	$314,489	$300,591	$511,817
	Crew shares (excluding skipper)	$37,074,363	$15,451,313	$13,399,581	$2,246,435	$2,135,997	$3,841,037
	Maintenance (routine & unexpected)	$7,597,395	$3,105,612	$2,810,601	$462,756	$440,829	$777,598
	Nets (hanging, repair, and web)	$6,448,105	$2,585,687	$2,438,853	$394,742	$376,714	$652,108
	Miscellaneous gear & supplies	$4,977,224	$2,231,591	$1,631,286	$295,343	$278,692	$540,313
	Raw fish tax	$4,841,985	$2,186,078	$1,570,843	$286,718	$270,344	$528,003
	Transportation	$4,878,269	$1,919,108	$1,884,613	$300,111	$286,902	$487,535
	Moorage, storage, and haul-out	$3,018,226	$1,159,956	$1,195,242	$186,769	$178,914	$297,344
	Insurance (P&I, hull, lay-up)	$5,187,074	$1,961,543	$2,088,165	$322,246	$309,117	$506,004
	Administrative services	$1,654,336	$662,268	$626,909	$101,320	$96,708	$167,130
	Annual permit fee	$577,350	$246,582	$202,314	$34,747	$32,958	$60,750
	Annual vessel license fee	$173,388	$91,579	$42,078	$9,739	$8,999	$20,992
	Property Tax	$696,336	$256,789	$287,292	$43,519	$41,833	$66,903
	Vessel and gear replacement	$6,149,746	$2,672,246	$2,106,234	$368,294	$348,708	$654,263
	Retained by permit holders	$72,668,608	$30,760,455	$25,758,280	$4,384,347	$4,162,374	$7,603,152

Note: Gross earnings are CFEC data reported in Table A-3. Total payments for each fishery are estimates from Tables B-1 and B-4. All payments are allocated among permit holders from different states in proportion to their share of gross earnings.

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[4] Probably non-Alaska residents should account for a larger share of transportation payments, but we had no clear way of estimating how much larger. Recall also that many Alaska residents who live in other parts of Alaska also face high transportation costs to get to Bristol Bay.

For the purposes of estimating economic impacts, what matters is not where the permit holders who made the payments lived, but what states they made payments to. Table B-6 shows our assumptions about how permit holders allocated payments among states, by permit holder residency and type of payment. A key assumption was that where permit holders made payments to depends upon where they lived. For example, as shown in the first row of the table, we assumed that Alaska residents spent 100% of their payments for food in Alaska, while residents of other states spent 57% of their payments for food in Washington (based on reported responses of Washington State residents to our November 2012 survey of drift gillnet permit holders).

Table B-6

Assumed Distribution of Expenditures by State, by Residency of Permit Holders

	Alaska permit holders		Washington permit holders		Oregon permit holders			California permit holders			Other permit holders		
Type of payment	AK	WA	AK	WA	AK	WA	OR	AK	WA	CA	AK	WA	OS
Food*	1.00		0.43	0.57	0.43	0.57		0.43	0.57		0.43	0.57	
Fuel, oil, & lubricants	1.00		1.00		1.00			1.00			1.00		
Crew shares (excluding skipper)	1.00			1.00			1.00			1.00			1.00
Maintenance (routine & unexpected)*	1.00		0.71	0.29	0.71	0.29		0.71	0.29		0.71	0.29	
Nets (hanging, repair, and web)*	1.00		0.71	0.29	0.71	0.29		0.71	0.29		0.71	0.29	
Miscellaneous gear & supplies	1.00		0.25	0.75	0.25	0.75		0.25	0.75		0.25	0.75	
Raw fish tax	1.00		1.00		1.00			1.00			1.00		
Transportation	1.00		0.10	0.90	0.10		0.90	0.10		0.90	0.10		0.90
Moorage, storage, and haul-out	1.00		1.00		1.00			1.00			1.00		
Insurance (P&I, hull, lay-up)	1.00			1.00		0.50	0.50		0.50	0.50		0.50	0.50
Administrative services	1.00			1.00			1.00			1.00			1.00
Annual permit fee	1.00		1.00		1.00			1.00			1.00		
Annual vessel license fee	1.00		1.00		1.00			1.00			1.00		
Property Tax	1.00		1.00		1.00			1.00			1.00		
Vessel and gear replacement	0.20	0.80		1.00		1.00			1.00			1.00	
Retained by permit holders	1.00			1.00			1.00			1.00			1.00

*Allocation of payments by state for food, maintenance and nets based on November 2012 survey of 21 Washington State permit holders. Other allocations based on authors' judgment and discussions with industry sources.

Table B7, which is calculated based on the assumptions in Tables B-6 and B-7, shows estimated permit holder payments by the states to which payments were made. Note that it is the geographical distribution of these payments among states which drives the geographical distribution of economic impacts of Bristol Bay fishing.

Table B-7

Assumed Permit Holder Payments by State

		AK	WA	OR	CA	Other states
Drift gillnet fishery	**Gross Earnings**	**$62,868,393**	**$50,354,315**	**$5,977,872**	**$5,746,199**	**$9,189,977**
	Food	$2,196,411	$1,237,570	$0	$0	$0
	Fuel, oil, & lubricants	$4,615,528	$0	$0	$0	$0
	Crew shares (excluding skipper)	$11,155,174	$12,480,230	$1,890,512	$1,817,245	$2,906,345
	Maintenance (routine & unexpected	$5,271,758	$1,159,967	$0	$0	$0
	Nets (hanging, repair, and web)	$4,631,865	$1,019,169	$0	$0	$0
	Miscellaneous gear & supplies	$1,820,811	$1,637,000	$0	$0	$0
	Raw fish tax	$3,305,851	$0	$0	$0	$0
	Transportation	$1,907,878	$1,640,285	$248,471	$238,842	$381,983
	Moorage, storage, and haul-out	$2,838,262	$0	$0	$0	$0
	Insurance (P&I, hull, lay-up)	$1,843,971	$2,609,667	$156,253	$150,197	$240,212
	Administrative services	$536,244	$599,941	$90,879	$87,357	$139,712
	Annual permit fee	$448,200	$0	$0	$0	$0
	Annual vessel license fee	$67,377	$0	$0	$0	$0
	Property Tax	$696,336	$0	$0	$0	$0
	Vessel and gear replacement	$339,170	$4,259,471	$0	$0	$0
	Retained by permit holders	$21,193,558	$23,711,015	$3,591,757	$3,452,558	$5,521,725
Set gillnet fishery	**Gross Earnings**	**$20,438,233**	**$5,223,620**	**$1,185,452**	**$1,061,650**	**$3,113,126**
	Food	$526,611	$141,157	$0	$0	$0
	Fuel, oil, & lubricants	$499,151	$0	$0	$0	$0
	Crew shares (excluding skipper)	$4,296,140	$919,351	$355,923	$318,752	$934,692
	Maintenance (routine & unexpected	$1,042,271	$123,400	$0	$0	$0
	Nets (hanging, repair, and web)	$712,693	$84,379	$0	$0	$0
	Miscellaneous gear & supplies	$1,097,188	$422,225	$0	$0	$0
	Raw fish tax	$1,536,135	$0	$0	$0	$0
	Transportation	$307,146	$55,867	$21,628	$19,370	$56,799
	Moorage, storage, and haul-out	$179,964	$0	$0	$0	$0
	Insurance (P&I, hull, lay-up)	$117,572	$47,181	$4,870	$4,362	$12,790
	Administrative services	$126,025	$26,969	$10,441	$9,350	$27,419
	Annual permit fee	$129,150	$0	$0	$0	$0
	Annual vessel license fee	$106,011	$0	$0	$0	$0
	Property Tax	$0	$0	$0	$0	$0
	Vessel and gear replacement	$195,279	$1,355,825	$0	$0	$0
	Retained by permit holders	$9,566,897	$2,047,265	$792,590	$709,816	$2,081,427
Total: drift gillnet and set gillnet fisheries	**Gross Earnings**	**$83,306,625**	**$55,577,935**	**$7,163,324**	**$6,807,849**	**$12,303,103**
	Food	$2,723,023	$1,378,728	$0	$0	$0
	Fuel, oil, & lubricants	$5,114,679	$0	$0	$0	$0
	Crew shares (excluding skipper)	$15,451,313	$13,399,581	$2,246,435	$2,135,997	$3,841,037
	Maintenance (routine & unexpected	$6,314,029	$1,283,367	$0	$0	$0
	Nets (hanging, repair, and web)	$5,344,557	$1,103,548	$0	$0	$0
	Miscellaneous gear & supplies	$2,917,999	$2,059,225	$0	$0	$0
	Raw fish tax	$4,841,985	$0	$0	$0	$0
	Transportation	$2,215,024	$1,696,152	$270,100	$258,211	$438,782
	Moorage, storage, and haul-out	$3,018,226	$0	$0	$0	$0
	Insurance (P&I, hull, lay-up)	$1,961,543	$2,656,848	$161,123	$154,559	$253,002
	Administrative services	$662,268	$626,909	$101,320	$96,708	$167,130
	Annual permit fee	$577,350	$0	$0	$0	$0
	Annual vessel license fee	$173,388	$0	$0	$0	$0
	Property Tax	$696,336	$0	$0	$0	$0
	Vessel and gear replacement	$534,449	$5,615,296	$0	$0	$0
	Retained by permit holders	$30,760,455	$25,758,280	$4,384,347	$4,162,374	$7,603,152

Source: Calculated from Tables B5 and B6.

Estimation of Processor Payments by Industry and State

Almost no data are publically available for Bristol Bay processors' costs or their payments by state, except for payments for labor, taxes and fish. Our other assumptions about processor payments are based almost entirely on discussions with industry sources and our best judgment about processors' average processing costs per pound.

The largest payment by processors is to fishermen to purchase fish. This payment is the ex-vessel value. We omit ex-vessel value from this discussion of processor payments. Our focus is on payments from the increase in value by processors, or total first wholesale value minus ex-vessel value.

Table B-8 shows the increase in value by Bristol Bay salmon processors in 2010, expressed both in dollars and also on a per pound basis. Note that value increase per pound may be expressed either as value increase per round (harvested) pound or as value increase per processed pound. Value increase per processed pound is smaller, because processed volume is smaller than harvested volume, as parts of the fish (heads, guts, etc.) are discarded during processing.

Table B-8

Increase in Value by Bristol Bay Salmon Processors, 2010

	Source or calculation	
Total first wholesale value FOB Bristol Bay	ADG&G COAR database data reported in Table A-12	$389,667,996
Ex-vessel value paid to permit holders	CFEC data reported in Table A-3	$165,158,835
Increase in value by Bristol Bay processors	First wholesale value - Ex-vessel value	$224,509,161
Production volume	ADG&G COAR database data reported in Table A-12	116,718,352
Harvest volume	CFEC data reported in Table A-3	181,226,355
Value increase per processed pound	Value increase/ Production volume	$1.92
Value increase per round (harvested) pound	Value increase / Harvest volume	$1.24

Table B-9 summarizes the assumptions which we used to estimate processor payments. We discussed our assumptions about payments to labor (wage payments to processing workers) in Table A10. For all other payment types, we assumed average total costs (payments) either per round pound or per processed pound, as shown in the table, based on discussions with processors and our best judgment.[5] Similarly, we allocated payments among states based on discussions with processors and our best judgment. Note that we allocated most payments to Washington, where all the large Bristol Bay processors are headquartered, and where most processing supplies and services are purchased.

Table B-9

Assumptions Used to Calculate Estimated Processor Payments in 2010
(expressed in dollars per round or processed pound)

Payment type	Assumptions about total payments: Assumed total payments per round lb	Assumed total payments per processed lb	Assumed shares of payments, by state: AK	WA	OR	CA	Other States
Total payments by processors (a)	$1.24	$1.92					
Labor	Estimates derived in Table A-10		Estimates derived in Table A-10				
Tendering	$0.17		20%	70%	10%		
Maintenance		$0.25	10%	90%			
Packaging		$0.20		60%			40%
Fishermen's support services	$0.10		30%	61%	9%		
Variable supplies		$0.09	20%	70%			10%
State & local taxes	$0.06						
Fuel		$0.06	25%	75%			
Utilities		$0.06	100%				
Insurance	$0.03			100%			
Food		$0.04	10%	90%			
Air travel		$0.04	5%	95%			
Fixed supplies		$0.03	10%	80%			10%
Rents & leases		$0.01	100%				
Other payments and returns to investment	Total payments minus other assumed payments		5%	90%			5%

(a) Source: Table B-8.

[5] Note that it is a very difficult task, even for processors, to estimate total costs or costs per pound in processing. Costs per pound vary, sometimes widely, by product, by year, and between processors. Labor costs depend on the timing and volume of the fish run, which affects the extent to which processors need to pay overtime to keep up with the volume of fish that must be processed, or alternatively pay food and housing costs for workers who are not working because there are no fish to be processed. To different extents and in different ways, processors allocate fixed costs between Bristol Bay salmon processing operations and other operations in Alaska and other states. Even where data are available about the costs for particular operations, it is difficult to generalize from these to the costs of the entire industry.

Table B-10 summarizes our assumptions about direct payments generated by Bristol Bay fishing and processing in 2010, based on the data, assumptions and analysis reported earlier in this appendix.

Table B-10

Assumed Direct Payments from Bristol Bay Fishing and Processing, by State, 2010

		State to which payments were made				
	Total	Alaska	Washington	Oregon	California	Other States
Total first wholesale value FOB Bristol Bay (a)	$389,667,996					
Value increase in Bristol Bay by processors (a)	$224,509,160					
Ex-vessel value paid to permit holders (a)	$165,158,836					
Payments by processors (b)	**$224,509,160**	**$43,355,550**	**$142,913,670**	**$6,257,029**	**$12,590,406**	**$19,392,506**
Labor	$33,963,492	$3,905,802	$9,045,069	$1,472,653	$12,590,406	$6,949,563
Tendering	$31,533,386	$6,306,677	$22,073,370	$3,153,339	$0	$0
Maintenance	$29,179,588	$2,917,959	$26,261,629	$0	$0	$0
Packaging	$23,343,670	$0	$14,006,202	$0	$0	$9,337,468
Fishermen's support services	$18,122,636	$5,436,791	$11,054,808	$1,631,037	$0	$0
Variable supplies	$10,504,652	$2,100,930	$7,353,256	$0	$0	$1,050,465
State & local taxes	$9,909,530	$9,909,530	$0	$0	$0	$0
Fuel	$7,409,027	$1,852,257	$5,556,770	$0	$0	$0
Utilities	$7,003,101	$7,003,101	$0	$0	$0	$0
Insurance	$5,436,791	$0	$5,436,791	$0	$0	$0
Food	$4,668,734	$466,873	$4,201,861	$0	$0	$0
Air travel	$4,668,734	$233,437	$4,435,297	$0	$0	$0
Fixed supplies	$3,501,551	$350,155	$2,801,240	$0	$0	$350,155
Rents & leases	$1,167,184	$1,167,184	$0	$0	$0	$0
Other payments and returns to investment	$34,097,086	$1,704,854	$30,687,377	$0	$0	$1,704,854
Payments by permit-holders (c)	**$165,158,836**	**$83,306,625**	**$55,577,935**	**$7,163,324**	**$6,807,849**	**$12,303,103**
Crew shares (excluding skipper)	$37,074,364	$15,451,313	$13,399,581	$2,246,435	$2,135,997	$3,841,037
Maintenance (routine & unexpected)	$7,597,395	$6,314,029	$1,283,367	$0	$0	$0
Nets (hanging, repair, and web)	$6,448,105	$5,344,557	$1,103,548	$0	$0	$0
Vessel and gear replacement (d)	$6,149,746	$534,449	$5,615,296	$0	$0	$0
Insurance (P&I, hull, lay-up)	$5,187,074	$1,961,543	$2,656,848	$161,123	$154,559	$253,002
Fuel, oil, & lubricants	$5,114,679	$5,114,679	$0	$0	$0	$0
Miscellaneous gear & supplies	$4,977,224	$2,917,999	$2,059,225	$0	$0	$0
Transportation	$4,878,269	$2,215,024	$1,696,152	$270,100	$258,211	$438,782
Raw fish tax	$4,841,985	$4,841,985	$0	$0	$0	$0
Food	$4,101,750	$2,723,023	$1,378,728	$0	$0	$0
Moorage, storage, and haul-out	$3,018,226	$3,018,226	$0	$0	$0	$0
Administrative services	$1,654,336	$662,268	$626,909	$101,320	$96,708	$167,130
Property tax	$696,336	$696,336	$0	$0	$0	$0
Annual permit fee	$577,350	$577,350	$0	$0	$0	$0
Annual vessel license fee	$173,388	$173,388	$0	$0	$0	$0
Retained by permit holders (e)	$72,668,608	$30,760,455	$25,758,280	$4,384,347	$4,162,374	$7,603,152

(a) Source: Table B-8; derived from data reported in Tables A-3 and A-12.

(b) Payments from value increase in Bristol Bay by processors (excludes payments to permit holders for fish). Calculated based on assumptions shown in Table B-9. Total payments by state are sums of payments estimated for payment categories.

(c) Payments from ex-vessel value paid to permit holders, from Table B-8.

(d) Assumed to equal depreciation

(e) Returns to permit holders' labor, management and investment

Estimation of Multiplier Economic Impacts of Bristol Bay Salmon Fishing and Processing

As discussed in Appendix D, we used the payment assumptions in Table B-10 as inputs to the national IMPLAN model as well as the state-level IMPLAN models for Alaska, Washington, Oregon and California to estimate multiplier (indirect and induced) economic impacts of Bristol Bay salmon fishing and processing in 2010. Table B-11 shows our resulting economic impact estimates.

Table B-11

Estimated Economic Impacts of Bristol Bay Salmon Fishing and Processing, 2010

Measure	Type of impact	Total US	Alaska	Washington	Oregon	California	Other states
Annual average employment	Direct effect	1,987	728	538	92	357	271
	Indirect effect	2,370	761	1,212	57	4	336
	Induced effect	3,482	578	1,025	106	245	1,529
	Multiplier effect	5,852	1,338	2,237	163	249	1,865
	Total effect	7,839	2,067	2,775	255	606	2,137
Income	Direct effect	$143,706,464	$50,117,570	$48,202,930	$8,103,434	$18,888,777	$18,393,752
	Indirect effect	$111,622,227	$37,988,890	$53,955,158	$2,704,107	$266,830	$16,707,242
	Induced effect	$156,420,295	$23,975,329	$43,666,690	$3,982,928	$11,854,314	$72,941,034
	Multiplier effect	$268,042,522	$61,964,219	$97,621,848	$6,687,035	$12,121,144	$89,648,276
	Total effect	$411,748,986	$112,081,789	$145,824,779	$14,790,469	$31,009,921	$108,042,028
Output value	Direct effect	$389,667,996	$126,662,175	$198,491,605	$13,420,353	$19,398,255	$31,695,609
	Indirect effect	$310,685,906	$88,414,231	$155,525,182	$7,149,132	$742,553	$58,854,809
	Induced effect	$490,516,601	$72,592,909	$132,244,901	$11,707,734	$35,799,082	$238,171,974
	Multiplier effect	$801,202,507	$161,007,140	$287,770,083	$18,856,865	$36,541,636	$297,026,783
	Total effect	$1,190,870,503	$287,669,315	$486,261,688	$32,277,218	$55,939,890	$328,722,392

APPENDIX C:
ESTIMATION OF DOWNSTREAM ECONOMIC IMPACTS OF THE BRISTOL BAY SALMON INDUSTRY

The downstream economic impacts of the Bristol Bay salmon industry are those driven by the transportation, secondary processing, warehousing, distribution and retailing of Bristol Bay salmon which occurs in other states. Table C-1 summarizes our estimates of the volumes of Bristol Bay salmon shipped to other states, the volumes sold in the U.S. domestic market, and selected other assumptions for our downstream economic impact analysis.

Table C-1
Assumed End-Markets for Bristol Bay Salmon Production, 2010

		Frozen	Canned	Fresh	Roe	Total
Millions of pounds	Total production	80.0	29.9	2.9	4.0	116.7
	Exported directly from Bristol Bay	39.8	0.0	0.5	4.0	44.3
	Shipped to other states	**40.2**	**29.9**	**2.4**	**0.0**	**72.4**
	Exported from other states	25.2	26.9	0.2	0.0	52.2
	Sold in US domestic market	**15.0**	**3.0**	**2.2**	**0.0**	**20.2**
Share of production	Total production	100%	100%	100%	100%	100%
	Exported directly from Bristol Bay	50%	0%	19%	100%	38%
	Shipped to other states	**50%**	**100%**	**81%**	**0%**	**62%**
	Exported from other states	31%	90%	6%	0%	45%
	Sold in US domestic market	**19%**	**10%**	**76%**	**0%**	**17%**
Other assumptions	Mode of transportation to other states	Sea	Sea	Air		
	Assumed states to which products were initially shipped	100% to Washington	50% to Washington 50% to Oregon			
	Types of secondary processing, warehousing and labeling prior to distribution to retailers	Filleting, portioning, reboxing, smoking	Warehousing & labeling			

Sources: ADF&G COAR Data; NMFS Fisheries Trade Data, and discussions with industry sources, as discussed in Appendix C.

In this appendix, we discuss our estimation of selected downstream economic impacts associated with transportation, secondary processing and other value adding, and distribution and retailing of Bristol Bay salmon. We organize our discussion as follows:

- Estimation of payments for marine transportation and secondary processing of frozen salmon
- Estimation of payments for marine transportation, warehousing and labeling of canned salmon
- Estimation of payments for distribution and retailing of Bristol Bay salmon products
- Estimation of economic impacts and contributions using IMPLAN models

Estimation of Payments for Marine Transportation and Secondary Processing of Frozen Salmon

Table C-2 documents our estimation of end-markets for Bristol Bay frozen salmon production. We based our estimates on data for total Alaska frozen sockeye production, total Bristol Bay frozen sockeye production, total US exports of frozen sockeye salmon and US exports of frozen sockeye directly from Alaska. Note that no data are available on exports of frozen sockeye salmon specifically from Bristol Bay. We assumed that the share of Bristol Bay frozen sockeye salmon which is exported directly is the same as the share of Alaska frozen sockeye salmon which is exported directly.

Table C-2

Estimation of End-Markets for Bristol Bay Frozen Sockeye Salmon, 2010

		Source	Volume (lbs)
Primary production of frozen sockeye salmon	Total Alaska production	a	113,360,944
	Bristol Bay production	b	79,961,576
	Bristol Bay share		71%
Exports of frozen sockeye salmon	Total US exports	c	92,087,890
	Exports from Alaska	c	56,428,432
	Exports from other states	c	35,659,458
Assumed end markets for total Alaska production	Exported from Alaska	c	56,428,432
	Exported from other states	c	35,659,458
	Consumed in the United States	d	21,273,054
Assumed end markets for Bristol Bay production	Exported from Alaska	e	39,803,007
	Shipped to other states	f	40,158,570
	Exported from other states	e	25,153,164
	Consumed in the United States	e	15,005,406
Assumed end-market shares for Bristol Bay production	Exported from Alaska	g	49.8%
	Shipped to other states	g	50.2%
	Exported from other states	g	31.5%
	Consumed in the United States	g	18.8%
	Share of shipments to other states consumed in the US	h	37.4%

(a) Source: Alaska Department of Fish and Game, Commercial Operator Annual Reports, data provided by ADF&G December 5, 2012.

(b) Source: Alaska Department of Fish and Game, Commercial Operator Annual Reports, data provided by ADF&G August 2, 2011.

(c) National Marine Fisheries Service, Foreign Trade in Fisheries Products website, http://www.st.nmfs.noaa.gov/st1/trade/

(d) Total Alaska production minus total exports

(e) Calculated as Bristol Bay share of total production x assumed end markets for total Alaska production. Assumes that markets for Bristol Bay sockeye salmon are the same, proportionally, as for all Alaska frozen sockeye.

(f) Total Alaska production minus volume exported from Alaska.

(g) Calculated from assumed end market volumes

(h) Volume consumed in the United States / Volume shipped to other states

Table C-3 documents our estimation of expenditures associated with marine transportation of Bristol Bay frozen sockeye salmon in 2010. Key assumptions are that the average cost of shipping frozen salmon to the United States was $.26/lb, and that all frozen salmon not exported directly was shipped to Washington State.

Table C-3

Estimation of Expenditures Associated with Marine Transportation of Bristol Bay Frozen Sockeye Salmon, 2010

Line	Assumption or calculation	Notes	Total	Washington
1	Volume of frozen Bristol Bay salmon shipped to other states (lbs)	a	40,158,570	
2	Average first wholesale price of frozen Bristol Bay salmon (FOB Bristol Bay)	b	$3.23	
3	Value of frozen salmon shipped to other states	c	$129,701,765	
4	Marine transportation cost per pound	d	$0.26	
5	Total expenditures for marine transportation = value increase in marine transportation	e	$10,441,228	
6	Total value after shipping to other states	f	$140,142,993	
7	Average value per pound after shipping	g	$3.49	
8	Assumed allocation of marine transportation expenditures, by state	d	100.0%	100.0%
9	Assumed marine transportation expenditures, by state	h	$10,441,228	$10,441,228

(a) Source: Table C-2; (b) Source: Table A-11; (c) Line 1 x Line 2; (d) Assumed based on discussions with industry sources; (e) Line 1 x Line 4; (f) Line 3 + Line 5; (g) Line 2 + Line 4; (h)

Table C-4 documents our estimation of the increase in value associated with secondary processing of Bristol Bay frozen sockeye salmon in other states. Key assumptions included the relative share of primary product forms produced in Bristol Bay (Line 3), the types of secondary processing in other states (Lines 6 and 7); the increase in value per pound for each type of secondary processing (Line 12), and the share of secondary processing occurring in Washington State (line 14). Note that all of these assumptions were based on discussions with industry sources. We had no independent source of data for these assumptions, and neither did our industry sources, except for their own costs and product allocations. Thus these assumptions should be considered reasonable approximations of the types of secondary processing which occurred and the extent of value added, but not precise estimates.

Table C-4

Estimation of Expenditures Associated with Secondary Processing of Bristol Bay Frozen Sockeye Salmon in Other States

Line	Assumption or calculation	Notes						
1	Total value of frozen Bristol Bay salmon shipped to other states, after shipping	a	$140,142,993					
2	Primary product forms produced in Bristol Bay	b	All	Vaccum-pack fillets	Vacuum-pack portions	IQF fillets	Headed & Gutted	
3	Assumed share of frozen salmon shipped to other states, by primary product form	b	100%	15%	5%	20%	60%	
4	Volume of frozen salmon shipped to the Lower 48 for secondary processing, by primary product form	c	40,158,570	6,023,785	2,007,928	8,031,714	24,095,142	
5	Average value per pound after shipping	a	$3.49	$3.49	$3.49	$3.49	$3.49	
6	Types of secondary processing in other states	b	All	Re-Boxing	Re-Boxing	Portions (includes cutting, reglazing, boxing & bagging)	Fillets (includes thawing, filleting, refreezing)	Smoking
7	Assumed share of secondary processing type, by primary product form	b		100%	100%	100%	90%	10%
8	Volume before secondary processing	d	40,158,570	6,023,785	2,007,928	8,031,714	21,685,628	2,409,514
9	Value before secondary processing	e	$140,142,993	$21,021,449	$7,007,150	$28,028,599	$75,677,216	$8,408,580
10	Assumed secondary processing yield	b		100%	100%	90%	70%	70%
11	Secondary product volume	f	32,126,856	6,023,785	2,007,928	7,228,543	15,179,939	1,686,660
12	Assumed increase in value per pound (secondary product weight basis)	b		$0.25	$0.25	$1.00	$2.10	$5.50
13	Increase in value in secondary processing	g	$50,390,974	$1,505,946	$501,982	$7,228,543	$31,877,873	$9,276,630
14	Assumed share of increase in value which occurs in Washington	b		100.0%	100.0%	100.0%	80.0%	80.0%
21	Estimated increase in value in Washington	i	$42,160,073	$1,505,946	$501,982	$7,228,543	$25,502,298	$7,421,304
26	Value after secondary processing	j	$190,533,966					

(a) Source: Table C-3; (b) Assumed based on discussions with industry sources; (c) Total volume from Table C-2, volume by secondary processing type allocated by shares in line 7; (d) Headed & gutted volume allocated by shares in line 7; (e) Line 5 x Line 11; (f) Line 8 x Line 10; (g) Line 11 x Line 12; (h) 20% non-Washington share allocated to other states in proportion their share of the total 2010 United States population excluding Washington state; (i) Line 13 x Line 14; (j) Line 13 x Lines 16-19.

Note that we only estimated the increase in value associated with secondary processing which occurs nationally and in Washington. Our estimates of downstream economic impacts for Oregon do not include impacts of secondary processing which occurs in Oregon.

Estimation of Payments for Marine Transportation, Warehousing and Labeling of Canned Salmon

All Bristol Bay canned salmon production is shipped to warehouses in Washington and Oregon where it is stored and labeled prior to shipments as sales are made over the course of the year. Table C-5 documents our estimation of payments associated with shipping, warehousing, storing and labeling canned salmon.[6]

Table C-5

Estimated Expenditures of Bristol Bay Processors for Canned Salmon Shipments to Warehouses, Storage, and Labeling, 2010

	Freight south	Handling in	Storage (assumes 5 months)	Labeling	Handling Out	Ink Jetting	All cost categories combined
Rates paid per case*							
Talls	$2.790	$0.169	$0.370	$0.700	$0.180	$0.044	
Halves	$1.500	$0.096	$0.295	$0.700	$0.107	$0.044	
Quarters & Four-Pound	$0.960	$0.048	$0.145	$0.720	$0.054	$0.044	
Total cost ($)**							
Talls	$673,070	$40,770	$89,260	$168,870	$43,424	$10,615	$1,026,009
Halves	$3,177,266	$203,345	$624,862	$1,482,724	$226,645	$93,200	$5,808,043
Quarters & Four-Pound	$124,372	$6,219	$18,785	$93,279	$6,996	$5,700	$255,351
All sizes combined	$3,974,708	$250,334	$732,908	$1,744,874	$277,065	$109,515	$7,089,402
Assumed share of payments by state							
Washington	50%	50%	50%	50%	50%	50%	
Oregon	50%	50%	50%	50%	50%	50%	
Estimated expenditures by state							
Washington	$1,987,354	$125,167	$366,454	$872,437	$138,532	$54,757	$3,544,701
Oregon	$1,987,354	$125,167	$366,454	$872,437	$138,532	$54,757	$3,544,701

Rates paid per case based on discussions with industry sources. **Assumes, based on discussions with processors and other industry sources, that 100% of Bristol Bay canned salmon was shipped to other states, and that 2010 production was 241,244 cases of talls, 2,118,117 cases of halves, and 129,554 cases of quarters and four-pound cans (24-can case basis).

[6] We consider these assumptions relatively reliable. The distribution of canned product by can sizes is based on a reliable industry data source, and the rates paid per case were provided by a Bristol Bay canned salmon processor.

Estimation of Payments for Distribution and Retailing of Bristol Bay Salmon Products

We next discuss, in turn, our assumptions for payments associated with the distribution and retailing in the United States of Bristol Bay frozen salmon, canned salmon, and fresh salmon. As discussed in Appendix D, we use these payment assumptions as inputs to the IMPLAN national model to estimate national economic contributions of retailing and distribution of Bristol Bay salmon products.

We had no data on the costs associated with distribution and retailing or the prices at which products were sold at retail. Costs and prices of Bristol Bay salmon products vary widely depending upon the geographic region, product form, and types of retail or food service outlet. It was far beyond the scope of this project to collect this kind of information.

For this reason, our assumptions about payments for distribution and retailing of Bristol Bay salmon are based upon a single simple assumption: that *distribution and retailing increases the value of Bristol Bay salmon products by 50% over their value after transportation to the United States and initial secondary processing and/or warehousing/labeling.* We consider this a conservative assumption based on retail prices we have observed for Bristol Bay salmon products in many parts of the United States, but it is *not* based on any formal data collection or analysis of sockeye salmon retail prices.[7]

Because they are based on this single simple but conservative assumption, our estimates of economic activity associated with distribution and retailing of Bristol Bay salmon products in the United States should be considered estimates of *what the associated jobs, income and output value would be if the average increase in value were 50%*, rather than estimates of what the jobs, income and output value actually are. Put differently, they may be viewed as a conservative estimate or low estimate of the potential jobs, income and output value associated with US distribution and retailing of Bristol Bay salmon products.

Tables C-6, C-7 and C-8 show how we estimated the increase in value in US distribution and retailing of Bristol Bay frozen, canned and fresh salmon, respectively.

[7] In estimating the total increase in value in 2010 value for all commercial marine fishery products in the United States, the National Marine Fisheries Service (NMFS, 2011) assumed a 62.7% mark-up of fishery inputs in secondary wholesale and processing of edible fishery products, a 33.4% markup of fishery inputs in retail trade from stores, and a 182.4% markup of fishery inputs in retail trade from food service (NMFS, Fisheries of the United States, 2010 (2011, page 79).

Table C-6

Estimation of Increase in Value in United States Distribution and Retailing of Bristol Bay Frozen Sockeye Salmon

Line	Assumption or calculation	Notes	Amount
1	Assumed value of Bristol Bay frozen sockeye salmon after secondary processing	a	$190,533,966
2	Share of secondary production consumed in the United States	b	37.4%
3	Value of secondary production consumed in the United States	c	$71,193,756
4	Assumed % increase in value from secondary wholesale value to retail	d	50.0%
5	Total value increase in distribution and retailing	e	$35,596,878
6	Total value after retail markup	f	$106,790,634

(a) Source: Table C-4; (b) Source: TableC-2; (c) Line 1 x Line 2; (d) Conservative assumption for average total markup percentage from wholesale value after secondary processing to retail value for sockeye products sold in the United States; (e) Line 3 x Line 4; (f) Line 3 + Line 5.

A challenge in estimating US consumption of Bristol Bay canned salmon is that reported United States exports of canned sockeye salmon significantly exceed reported Alaska production of canned sockeye salmon, as shown in Figure C1. We are unable to explain this. Clearly, the United States cannot continuously export more canned sockeye salmon than it produces. Possibly the Alaska production data are under-reported, the US export data are miscoded, or the two data sources calculate volume differently. In any case, the data suggest that most canned Alaska sockeye salmon are probably exported. However, the fact that canned sockeye salmon can readily be found on US retail shelves shows that clearly some canned sockeye salmon is consumed domestically. For the purposes of our analysis, we made the simple assumption that 90% of Bristol Bay canned sockeye salmon is exported, and 10% is consumed domestically (Table C-7).

Figure C-1

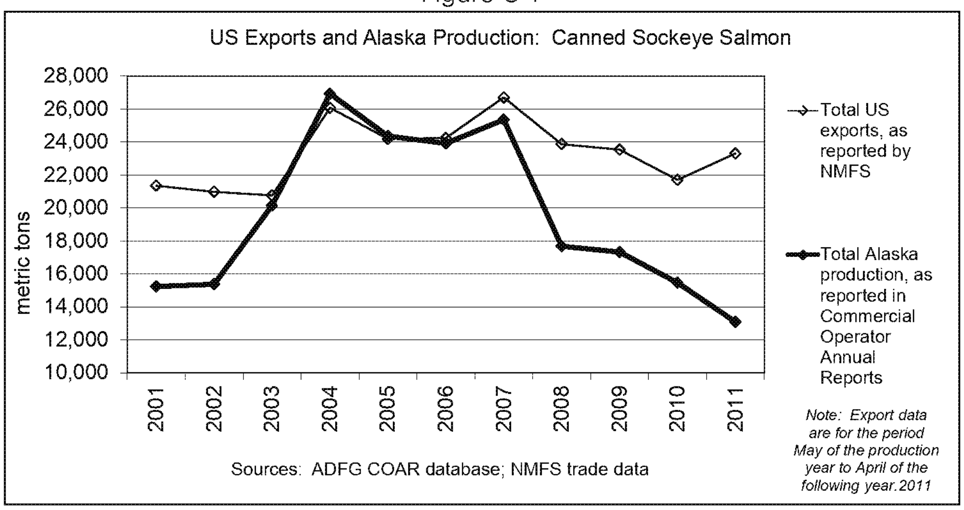

Table C-7

Estimation of Increase in Value in United States Distribution and Retailing of Bristol Bay Canned Sockeye Salmon

Line	Assumption or calculation	Notes	Amount
1	Total first wholesale value of Bristol Bay canned salmon production FOB Bristol Bay	a	$105,376,086
2	Share of Bristol Bay canned salmon shipped to other states	b	100.0%
3	Estimated increase in value in shipping	c	$3,974,708
4	Estimated increase in value in warehousing/labeling	c	$3,114,695
5	Total value after shipping and warehousing/labeling	d	$112,465,488
6	Assumed share sold in the United States	e	10%
7	Total value FOB warehouse of product sold in the United States	f	$11,246,549
8	Assumed increase in value in distribution and retailing (%)	g	50%
9	Assumed increase in value in distribution and retailing ($)	h	$5,623,274
10	Assumed retail value	10	$16,869,823

(a) Source: Table A-12; (b) Assumed based on US trade data and discussions with industry sources; (c) Calculated from Table C-4; (d) Sum of Lines 1, 3 and 4; (e) Assumed: see discussion in text; (f) Line 5 x Line 6. (g) Assumed: see discussion in text; (h) Line 7 x Line 8; (i) Line 7 + Line 9.

C-8 shows how we estimated the increase in value in US distribution and retailing of Bristol Bay fresh salmon. The table includes an assumption that the air freight rate for all Bristol Bay fresh salmon averages $.50/lb. We have no data for average air freight rates, but consider this a reasonable assumption. Alaska Airlines' Seafood Express Rate Sheet (rates and destinations effective September 14, 2011) lists a rate of $.52/lb for 1000-lb shipments from Dillingham and King Salmon (Zone 1C) to Seattle (Zone 4) (http://www.alaskaair.com/~/media/Files/PDF/Cargo/FZ-27-Seafood-Express-201303.pdf). We include this payment for air freight with our assumptions for payments driving the economic contribution of retailing and distribution of Bristol Bay salmon.

Table C-8

Analysis of End-Markets for Bristol Bay Fresh Salmon Production and Estimation of Increase in Value in US Distribution and Retailing of Bristol Bay Fresh Salmon, 2010

		Notes	Volume (lbs)
Fresh sockeye salmon production (lbs)	Total Alaska production	a	17,463,319
	Bristol Bay production	b	2,899,396
	Bristol Bay share of total Alaska production		17%
Bristol Bay fresh salmon first wholesale value & price	Bristol Bay first wholesale value	b	$6,119,811
	Bristol Bay average first wholesale price ($/lb)	b	$2.11
Exports of fresh sockeye salmon (lbs)	Total US exports	c	4,242,182
	Exports from Alaska	c	3,236,734
	Exports from other states	c	1,005,448
Assumed end markets for total Alaska production (lbs)	Exports from Alaska		3,236,734
	Exports from other states		1,005,448
	US domestic consumption	d	13,221,138
Assumed end market shares for Bristol Bay production	Exported from Bristol Bay	e	19%
	Exported from other states	e	6%
	US domestic consumption	e	76%
Assumed end markets for Bristol Bay production (lbs)	Exported from Bristol Bay	f	537,388
	Exported from other states	f	166,932
	US domestic consumption	f	2,195,076
Air freight expenditures	Assumed air freight rate for all Bristol Bay fresh salmon ($/lb)	g	$0.50
	Estimated air freight expenditures		$1,449,698
	Average first wholesale price after air freighting ($/lb)		$2.61
Retail increase in value	Assumed retail markup percentage for US domestic production over Bristol Bay wholesale value and air freight	h	50%
	Assumed retail increase in value for Bristol Bay fresh salmon consumed in the United States	i	$2,865,364

(a) Source: Alaska Department of Fish and Game, Commercial Operator Annual Reports, data provided by ADF&G December 5, 2012.

(b) Source: Alaska Department of Fish and Game, Commercial Operator Annual Reports, data provided by ADF&G August 2, 2011.

(c) National Marine Fisheries Service, Foreign Trade in Fisheries Products website, http://www.st.nmfs.noaa.gov/st1/trade/

(d) Alaska production minus total exports

(e) Assumes the same end market shares for Bristol Bay fresh sockeye are for all Alaska sockeye

(f) Calculated from Bristol Bay production and assumed end market shares

(g) Assumed based on Alaska Airlines Seafood Express Rate Sheet (http://www.alaskaair.com/~/media/Files/PDF/Cargo/FZ-27-Seafood-Express-201303.pdf)

(h) Conservative assumption for average total markup percentage from wholesale value after air-freighting to retail value for sockeye products sold in the United States

(i) 2,195,076 lbs consumed domestically x $2.61 wholesale price x 50% markup.

Estimation of Economic Impacts and Contributions Using IMPLAN Models

Table C-9 summarizes our assumptions of the payments generated by selected "downstream" economic activities in the United States utilizing Bristol Bay salmon in 2010.

Table C-9

Summary of Assumptions for Payments Generated in Selected Bristol Bay Salmon 'Downstream' Economic Activities, 2010

	Activity	Source table	United States	Washington	Oregon
Assumptions used to estimate economic impacts of shipping to other states and secondary processing	Marine transportation of frozen salmon	C-3	$10,441,228	$10,441,228	
	Frozen salmon secondary processing	C-4	$50,390,974	$42,160,073	
	Marine transportation of canned salmon	C-5	$3,974,708	$1,987,354	$1,987,354
	Canned salmon warehousing and labeling	C-5	$3,114,695	$1,557,347	$1,557,347
Assumptions used to estimate economic contributions in nationwide distribution and retailing	Distribution & retailing of frozen salmon	C-6	$35,596,878		
	Distribution & retailing of canned salmon	C-7	$5,623,274		
	Air transportation of fresh salmon	C-8	$1,449,698		
	Distribution & retailing of fresh salmon	C-8	$2,865,364		

As discussed in Appendix D, we used the payment assumptions in the top half of Table C-9 as inputs to the national IMPLAN model and the state-level IMPLAN models for Washington and Oregon, to estimate downstream economic impacts of marine transportation of frozen and canned salmon, secondary processing of frozen salmon, and warehousing and labeling of canned salmon. Table C-10 shows our estimates of the combined economic impacts of these activities.

Table C-10

Estimated 'Downstream' Economic Impacts of Marine Transportation of Frozen and Canned Salmon, Secondary Processing of Frozen Salmon, and Warehousing and Labeling of Canned Salmon

Measure	Type of impact	Total US	Washington	Oregon
Annual average employment	Direct effect	191	156	15
	Indirect effect	243	103	12
	Induced effect	319	126	12
	Multiplier effect	563	229	24
	Total effect	754	385	39
Income	Direct effect	$13,110,295	$10,968,827	$854,146
	Indirect effect	$15,750,564	$6,340,422	$518,616
	Induced effect	$14,312,471	$5,388,473	$443,453
	Multiplier effect	$30,063,035	$11,728,895	$962,070
	Total effect	$43,173,329	$22,697,723	$1,816,216
Output value	Direct effect	$67,813,775	$56,014,272	$3,513,633
	Indirect effect	$66,205,592	$21,131,321	$1,346,748
	Induced effect	$44,774,640	$16,309,863	$1,302,219
	Multiplier effect	$110,980,232	$37,441,185	$2,648,967
	Total effect	$178,794,007	$93,455,456	$6,162,600

As discussed in Appendix D, we used the payment assumptions in the bottom half of Table C-9 as inputs to the national IMPLAN model to estimate nationwide economic activity associated with distribution and retailing. These estimates are shown in Table C-11.

Table C-11

Estimated Economic Contributions of Distribution and Retailing of Bristol Bay Salmon Products in the United States, 2010

Measure	Type of effect	Activity
Annual average employment	Direct contribution	787
	Indirect contribution	112
	Induced contribution	312
	Multiplier contribution	425
	Total contribution	1,212
Income	Direct contribution	$22,691,854
	Indirect contribution	$5,625,023
	Induced contribution	$14,006,490
	Multiplier contribution	$19,631,513
	Total contribution	$42,323,367
Output value	Direct contribution	$45,535,217
	Indirect contribution	$16,938,512
	Induced contribution	$43,815,952
	Multiplier contribution	$60,754,465
	Total contribution	$106,289,681

Summary of Estimated Direct, Multiplier and Downstream Economic Impacts and Contributions

Tables C-12, C-13 and C-14 on the following page summarize all of the direct, multiplier and downstream economic impacts and contributions we estimated for this study.

Table C-11

Estimated Employment Impacts and Contributions of the Bristol Bay Salmon Industry, 2010 (annual average employment)

Impact driver	Type of impact	Total US	Alaska	Washington	Oregon	California	Other states
Fishing and primary processing in Bristol Bay	Direct impact	1,987	728	538	92	357	271
	Indirect impact	2,370	761	1,212	57	4	336
	Induced impact	3,482	578	1,025	106	245	1,529
	Multiplier impact	5,852	1,338	2,237	163	249	1,865
	Total impact	7,839	2,067	2,775	255	606	2,137
Shipping to other states and secondary processing	Direct impact	191		156	15		
	Indirect impact	243		103	12		
	Induced impact	319		126	12		
	Multiplier impact	563		229	24		
	Total impact	754		385	39		
Nationwide distribution and retailing	Direct contribution	787					
	Indirect contribution	112					
	Induced contribution	312					
	Multiplier contribution	425					
	Total contribution	1,212					
Total impacts and contributions		9,804					

Table C-12

Estimated Income Impacts and Contributions of the Bristol Bay Salmon Industry, 2010 ($)

Impact driver	Type of impact	Total US	Alaska	Washington	Oregon	California	Other states
Fishing and primary processing in Bristol Bay	Direct impact	$143,706,464	$50,117,570	$48,202,930	$8,103,434	$18,888,777	$18,393,752
	Indirect impact	$111,622,227	$37,988,890	$53,955,158	$2,704,107	$266,830	$16,707,242
	Induced impact	$156,420,295	$23,975,329	$43,666,690	$3,982,928	$11,854,314	$72,941,034
	Multiplier impact	$268,042,522	$61,964,219	$97,621,848	$6,687,035	$12,121,144	$89,648,276
	Total impact	$411,748,986	$112,081,789	$145,824,779	$14,790,469	$31,009,921	$108,042,028
Shipping to other states and secondary processing	Direct impact	$13,110,295		$10,968,827	$854,146		
	Indirect impact	$15,750,564		$6,340,422	$518,616		
	Induced impact	$14,312,471		$5,388,473	$443,453		
	Multiplier impact	$30,063,035		$11,728,895	$962,070		
	Total impact	$43,173,329		$22,697,723	$1,816,216		
Nationwide distribution and retailing	Direct contribution	$22,691,854					
	Indirect contribution	$5,625,023					
	Induced contribution	$14,006,490					
	Multiplier contribution	$19,631,513					
	Total contribution	$42,323,367					
Total impacts and contributions		$497,245,682					

Table C-12

Estimated Output Value Impacts and Contributions of the Bristol Bay Salmon Industry, 2010 ($)

Impact driver	Type of impact	Total US	Alaska	Washington	Oregon	California	Other states
Fishing and primary processing in Bristol Bay	Direct impact	$389,667,996	$126,662,175	$198,491,605	$13,420,353	$19,398,255	$31,695,609
	Indirect impact	$310,685,906	$88,414,231	$155,525,182	$7,149,132	$742,553	$58,854,809
	Induced impact	$490,516,601	$72,592,909	$132,244,901	$11,707,734	$35,799,082	$238,171,974
	Multiplier impact	$801,202,507	$161,007,140	$287,770,083	$18,856,865	$36,541,636	$297,026,783
	Total impact	$1,190,870,503	$287,669,315	$486,261,688	$32,277,218	$55,939,890	$328,722,392
Shipping to other states and secondary processing	Direct impact	$67,813,775		$56,014,272	$3,513,633		
	Indirect impact	$66,205,592		$21,131,321	$1,346,748		
	Induced impact	$44,774,640		$16,309,863	$1,302,219		
	Multiplier impact	$110,980,232		$37,441,185	$2,648,967		
	Total impact	$178,794,007		$93,455,456	$6,162,600		
Nationwide distribution and retailing	Direct contribution	$45,535,217					
	Indirect contribution	$16,938,512					
	Induced contribution	$43,815,952					
	Multiplier contribution	$60,754,465					
	Total contribution	$106,289,681					
Total impacts and contributions		$1,475,954,191					

APPENDIX D:
USE OF IMPLAN MODELS FOR ECONOMIC IMPACT ANALYSIS

We estimated economic impacts of the Bristol Bay salmon industry using the IMPLAN impact assessment modeling system. IMPLAN was originally developed by the US Forest Service and is now made available by subscription through MIG, Inc. (http://implan.com/V4/Index.php). It is widely used for economic impact analyses by federal, state, and local governments, universities, and private consultants. At the center of IMPLAN is a set of national, state level and country level input-output models constructed with region specific data derived primarily from government sources including the Bureau of Economic Analysis, the Bureau of Labor Statistics, and the US Census.

Each input output model is a matrix representation of the inter-industry monetary flows within the region (including governments and households). This matrix can be used to estimate the total employment (measured as annual average jobs), income, gross receipts (output value), and value added (output minus the cost of intermediate inputs) generated by the introduction of a new economic activity into a region (or of an activity currently taking place within the region). The model takes as input a set of industry specific expenditures and tracks the flow of those dollars as they are re-spent through the other industries within the region (the multiplier effect). The output of the model is a series of estimates (employment, income, gross receipts, and value added by industry) of the total economic activity in the region attributable to the new activity.

These estimates include both the indirect and the induced effects of the activity. The indirect effect is a measure of effects of the business to business purchases while the induced effect is a measure of effects of purchases by households from income generated by the business expansion.

For this analysis we used the IMPLAN national input output model to estimate the total economic significance of Bristol Bay salmon fishing and processing, as well as downstream activities, for the entire nation.

We used state level models for the four western states—Alaska, Washington, Oregon, and California-- to generate estimates of economic impacts of Bristol Bay salmon fishing and processing in each of these states.[8]

We also used the Washington model to estimate economic impacts of marine transportation, secondary processing of frozen salmon, and canned salmon warehousing and labeling in Washington. Similarly, we

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[8] Note that the multiplier (induced and indirect) impacts estimated for the four western states reflect only those driven by the direct effects in each state. For example, the multiplier effects estimated for California are only those resulting from payments made to California households or California businesses, as those payments generate additional payments within California. They exclude those resulting from payments made to Washington households or businesses which generate payments to California households or businesses. Thus, by using state level models, we understate the multiplier effects of Bristol Bay salmon fishing and processing within the four western states. To address this concern, we created a separate model that combined the models for the four western states. This four-state model contained a set of inter-regional trade flow matrices which captured the interstate flow of purchases by an industry in one state from each of the others. However, the difference in estimated multiplier impacts was so small that we only report the estimates based on the state level models.

also used the Oregon model to estimate economic impacts of canned salmon warehousing and labeling in Oregon.

We estimated direct, indirect and induced economic impacts of Bristol Bay salmon fishing and processing for other states as the difference between national economic impacts and estimated economic impacts for each of the four western states.

Allocation of Payments to IMPLAN Industries

The inputs that generate the model results are payments associated with fishing, primary processing, transportation, secondary processing, marine transportation of frozen and canned salmon, air transportation of fresh salmon, secondary processing of frozen salmon, warehousing and labeling of canned salmon, and distribution and retailing of Bristol Bay salmon products. To use the IMPLAN model, we needed to allocate these payments to IMPLAN industry sectors.

Tables D-1 shows our allocations from payment categories to IMPLAN industries for Bristol Bay fishing. Where there was not an obvious match these allocations were necessarily somewhat subjective. Note however that payments to all industries have multiplier effects, and particularly for smaller payments the allocations have relatively little effect on the overall estimated impacts of the Bristol Bay salmon industry.

Table D-1
Allocation of Bristol Bay Fishing Payments to IMPLAN Industries

Fishing payment category	IMPLAN commodity code	IMPLAN Industry
Maintenance (routine & unexpected)	3039	Maintained and repaired nonresidential structures
Nets (hanging, repair, and web)	3085	All other textiles
Fuel, oil, & lubricants	3115	Refined petroleum products
Depreciation (boat building & repair)	3291	Boats
Miscellaneous gear & supplies	3311	Sporting and athletic goods
Food	3324	Retail services-food and beverage
Transportation	3332	Air transportation services
Moorage, storage, and haul-out	3340	Warehousing and storage services
Insurance (P&I, hull, lay-up)	3357	Insurance
Administrative services	3386	Business support services
Raw fish tax	3437	State & local government ,non-education
Annual permit fee	3437	State & local government ,non-education
Annual vessel license fee	3437	State & local government ,non-education
Property tax	3437	State & local government ,non-education

We allocated crew share payments and returns to labor, management and investment to household categories. IMPLAN has nine different income groupings with each of these categories having a distinct spending pattern based on the National Income and Product Accounts (NIPA) and the personal consumption expenditure. We allocated crew share payments to households who earn between 25,000 and 35,000 (sector 10004). We allocated permit holder net earnings to households who earn between 75,000 and 100,000 (sector 10007).

Tables D-2 shows our allocations from payment categories to IMPLAN industries for Bristol Bay primary processing. We allocated processing labor payments to households who earn between 25,000 and 35,000 (sector 10004). We allocated processor profits to households who earn more than 150,000 (sector 10009).

Table D-2

Allocation of Bristol Bay Processing Payments to IMPLAN Industries

Processing payment category	IMPLAN commodity code	IMPLAN Industry
Utilities	3031	Elctricity and distribution services
Maintenance	3039	Maintained and repaired nonresidential structures
Fuel	3115	Refined petroleum services
Food	3324	Retail services-food and beverage
Air travel	3332	Air transportation Services
Tendering	3334	Water transportation Services
Insurance	3357	Insurance
Rents & leases	3365	Commercial and Industrial machinery and equipment rental
Fishermen's support services	3386	Business support services
State & local taxes	3437	State & local government, non education
Fixed supplies	33%: 3149 67%: 3236	Other plastic products & computer terminals Other computer peripheral equipment
Variable supplies	62%: 3014 38%: 3061	Animal products Seafood products
Packaging	88%: 3190 12%: 3142	Metal cans ,boxes,etc & plastics Packaging materials.

Table D-3 shows our allocations of payments from downstream industries to IMPLAN industries.

Table D-3

Allocation from Downtream Industries to IMPLAN Industries

Downstream industry	IMPLAN commodity code	IMPLAN Industry
Marine transportation	3334	Water transportation services
Air transportation	3332	Air transportation services
Frozen salmon secondary processing	50%: 3228 50%: 3142	Material handling equipment Plastics packaging materials and unlaminated films & sheets
Canned salmon warehousing & labeling	50%: 3061 50%: 3389	Seafood products Other suport services
Distribution and retailing of salmon products	3324	Retail services-food and beverage

APPENDIX E:
ESTIMATION OF EXPORT VALUE AND DOMESTIC CONSUMPTION OF BRISTOL BAY SOCKEYE SALMON

Chapter VI includes estimates of the value of Bristol Bay sockeye salmon exports and of domestic consumption of Bristol Bay sockeye salmon.

To develop these estimates, we began by calculating the share of Bristol Bay production in total Alaska production of frozen sockeye salmon, canned sockeye salmon, fresh sockeye salmon and sockeye salmon roe, using ADF&G COAR data. To estimate export volumes and value of Bristol Bay sockeye salmon products, we multiplied these shares by the total US export volumes and values of the corresponding products, as reported in NMFS Fisheries Trade data.

We estimated total US domestic consumption of frozen sockeye salmon as total Alaska production minus total US exports of frozen sockeye salmon, as reported in NMFS Fisheries Trade data. We estimated US domestic consumption of frozen Bristol Bay sockeye salmon by multiplying estimated total US domestic consumption by the Bristol Bay share of Alaska frozen sockeye production.

We estimated the Bristol Bay share of selected US seafood product exports as shown in the Table E-1.

Table E-1

Value of Bristol Bay Sockeye Salmon Exports as a Percentage of Value of Selected US Fish Exports and Import Product Categories, 2010

Export or Import Category	Source	Value	Bristol Bay sockeye export value as a % of value
Total Bristol Bay sockeye salmon exports (estimated)	a	$252,284	
Frozen	a	134,937	
Canned	a	95,702	
Fresh	a	1,728	
Roe	a	19,917	
Total US sockeye salmon exports, all products	b	$341,977	74%
Frozen	b, e	$191,299	71%
Canned	b, e	$109,190	88%
Fresh	b, e	$10,409	17%
Roe	c, e	$31,078	64%
Total US salmon exports, all species and products	d	$898,790	28%
Fresh and frozen salmon	d, e	$591,587	23%
Canned salmon	d, e	$179,424	53%
Salmon roe	d, e	$127,779	16%
Total US edible fish exports, all species	d	$4,379,760	6%
Total US salmon imports (all species and products)	d	$1,755,481	14%
Total US edible fish imports (all species and products)	d	$14,807,678	2%

(a) Estimates in Table E-1. Note: Value is for calendar year exports.
(b) NMFS fisheries trade data reported in Table E-1. Note: Export value shares correspond to shares of Bristol Bay production in total Alaska production.
(c) Sockeye salmon roe production as reported in ADFG COAR data; assumed to be 100% exported.
(d) NMFS, Fisheries of the United States, 2010.
(e) Percentage is % of corresponding Bristol Bay sockeye salmon export product.

APPENDIX F:
COMPARISONS WITH OTHER RECENT ECONOMIC IMPACT ANALYSES OF THE BRISTOL BAY SALMON INDUSTRY

Two recent analyses, listed in the box below, estimated economic impacts of the Bristol Bay salmon industry. We refer to these as the "Goldsmith" and "Schwoerer" analyses.[9]

Both the Goldsmith and Schwoerer analyses were relatively small parts of larger studies, involving other authors, which examined a much wider range of economic topics related to Bristol Bay salmon, including economic impacts of sport and subsistence fisheries and net economic values of Bristol Bay salmon resources. Our discussion here is limited solely to these studies' analyses of economic impacts of the commercial salmon fishery.

Table F-1 (on the following page) compares the employment and income impact estimates of the Goldsmith and Schwoerer analyses with those of this report. For those impacts for which all three studies estimated comparable types of impacts, the estimated economic impacts were fairly close and certainly consistent with each other, given the fact that the analyses were done for three different years.

The major difference between the studies is that *the Goldsmith and Schwoerer analyses estimated only those multiplier impacts which occurred in Alaska.* They did not attempt to estimate the multiplier impacts which occurred in other states. Since the multiplier impacts which occur outside Alaska (the shaded cells in the table) are large—this study estimates they are two to three times as large as those which occur in Alaska—the total economic impacts estimated in the Goldsmith and Schwoerer analyses are much smaller.

The Goldsmith and Schwoerer analyses also did not estimate downstream economic impacts and contributions of the Bristol Bay salmon industry, as was done for this study.

Recent Economic Impact Analyses of the Bristol Bay Salmon Industry

Goldsmith, Scott. 2007. *Economic Significance.* Pages 92-105 of Duffield, J., D. Patterson, and C. Neher, *Economics of Wild Salmon Watersheds: Bristol Bay, Alaska (*Report prepared for Trout Unlimited, Alaska, February 2007).
http://www.bber.umt.edu/pubs/survey/Economics%20of%20Wild%20Salmon%20 Ecosystems%20in%20Bristol%20Bay_2007.pdf

Schwoerer, Tobias. *Economic Significance of Healthy Salmon Ecosystems in the Bristol Bay Region.* Pages 171-198 of *Bristol Bay Wild Salmon Ecosystem Baseline Levels of Economic Activity and Values*, in Volume 3, Appendix E of Environmental Protection Agency, *An Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska*, External Review Draft, EPA 910-R-12-004d, May 2012. http://www2.epa.gov/bristolbay.

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[9] Dr. Scott Goldsmith is one of the authors of this study, and a colleague of the other authors at the University of Alaska Anchorage Institute of Social and Economic Research (ISER). Tobias Schwoerer is also an ISER colleague of the authors.

Table F-1

Comparison of Selected Recent Economic Impact Analyses of the Bristol Bay Salmon

			Goldsmith	Schwoerer	This report
Type of impact	Year for which impacts were estimated		2005	2009	2010
	Pages reporting economic estimates		98	183	21, 74
Estimated economic impacts of Bristol Bay salmon and processing	Seasonal employment	*Direct impacts*			
		Alaska	4,177	4,341	4,369
		Other states	8,308	7,231	7,552
	Annual average employment	*Direct impacts*			
		Alaska	1,008	707	728
		Other states	1,968	1,190	1,259
		Multiplier impacts			
		Alaska	1,263	1,586	1,338
		Other states			**4,514**
		Total impacts			
		Alaska	2,271	2,293	2,066
		Other states			**5,773**
	Income ($000)	*Direct impacts*			
		Alaska	26,527	40,307	50,118
		Other states	52,693	94,233	93,589
		Multiplier impacts			
		Alaska	41,371	54,705	61,694
		Other states			**206,348**
		Total impacts			
		Alaska	67,797	95,102	112,082
		Other states			**299,667**
Downstream impacts	Total annual average employment				**1,212**
	Total income ($000)				**42,323**

Note: Shaded cells are impacts estimated in this report which were not estimated in the Goldsmith and Schwoerer analyses.

APPENDIX G: DATA SOURCES FOR THE BRISTOL BAY SALMON INDUSTRY

A rich variety of data exists for the Bristol Bay salmon industry. However, the data can be difficult and confusing to work with, for a number of reasons. Some data are not published, and are available only upon request from Alaska state government agencies. Many data series are available only for limited periods of time: some have been discontinued and are not available for recent years; others have been collected or published only beginning relatively recently and are not available for earlier years. Many data series are inconsistent: reports published by the same agency in different years may provide different data for the same series. Preliminary data (particularly for prices and values) are often revised later, sometimes substantially. Some kinds of data are confidential except when aggregated for minimum threshold numbers of permit holders, processors or other firms. Some kinds of data are proprietary (particularly price data gathered by private market information services). What data mean, how they were collected or estimated, and how reliable they are is often undocumented and unclear. For all these reasons, technical economic analysis of Bristol Bay salmon industry data can be confusing for both the analyst and for the reader.

This appendix describes the major data sources we used for this analysis, and a few other useful sources, in alphabetical order of the names used to refer to them (shown in **bold font**).

ADFG Commercial Operator Annual Report (COAR) Data. In April of every year, all Alaska fish processors are required to submit "Commercial Operator Annual Reports" to the Alaska Department of Fish and Game. In these reports they are required to report the total volume of fish purchased, by species and area; the total amount paid for fish purchased, by species and area; the total volume (weight) of production, by product, species and area; and the total first wholesale value of production. Information about the COAR reporting forms is at:

http://www.adfg.alaska.gov/index.cfm?adfg=fishlicense.coar

The COAR data are not posted on the internet or published regularly by ADF&G (which is unfortunate), but are available by special request from ADF&G. The data used for this report were provided on August 2, 2011 to Gunnar Knapp and were saved as Excel file "Statewide and regional COAR production 1984-2011 provided by ADFG 8-2-11.xls." Average "first wholesale prices" were calculated by dividing first wholesale value by production volume.

ADFG Alaska Commercial Salmon Harvests and Ex-vessel Values Reports. These reports provide summary annual data for each of 11 Alaska salmon harvest areas. The data include average fish weight, average price per pound, numbers of fish, harvest volume in pounds, and estimated value in dollars. Prices for the most recent year are generally preliminary estimates based on fish tickets and reports from area managers. Prices for earlier years are generally based on "Commercial Operators Annual Report and area staff reports." The reports are available at:

http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmoncatch

ADFG Salmon Ex-Vessel Price Time Series by Species 1984-2011. This is a two-page table of ex-vessel prices by species, 1984-2011, for the following areas: Cook Inlet, Kodiak, Alaska Peninsula, Bristol

Bay, Prince William Sound, Southeast, and Statewide. The original source is cited as the Commercial Operator Annual Reports database.
http://www.adfg.alaska.gov/static/fishing/PDFs/commercial/84-11exvl.pdf

ADLWD Bristol Bay Region Fishing and Seafood Industry Data. The Alaska Department of Labor and Workforce Development (ADLWD) Research and Analysis Division posts a variety of economic information for the Bristol Bay Seafood Industry on its "Bristol Bay Region Fishing and Seafood Industry Data" website at:

http://labor.alaska.gov/research/seafood/seafoodbristol.htm.

ADLWD Bristol Bay Region Fishing Employment Estimates. These are fish harvesting employment estimates posted on the ADLWD Bristol Bay Region Fishing and Seafood Industry Data website as Alaska Department of Labor and Workforce Development, Fish Harvesting Employment by Species and Month, 2001-2011, Bristol Bay Region,
http://laborstats.alaska.gov/seafood/BristolBay/BBAvgMonthlyRegSpc.pdf.

ADLWD Bristol Bay Region Seafood Processing Employment and Earnings Data. These are data for the years 2001-2011 for Bristol Bay region seafood processing total worker count, percent nonresident workers, wages, and percent nonresident wages, posted on the ADLWD Bristol Bay Region Fishing and Seafood Industry Data website as Alaska Department of Labor and Workforce Development, Bristol Bay Region Seafood Industry, 2001-2011, Processing, at:
http://laborstats.alaska.gov/seafood/BristolBay/BBSFPOver.pdf.

ADOR Annual Salmon Price Reports. Every year, "large" Alaska salmon processors (those with sales exceeding 1 million pounds in the previous calendar year) are required to report sales volumes and first wholesale values for major salmon product categories to the Alaska Department of Revenue. Annual statewide summary reports of these data are available on the Alaska Department of Revenue's Tax Division Reports website at:

http://www.tax.alaska.gov//programs/reports.aspx

Once on this page, click on "Alaska Salmon Price/Production." Note that the "Annual Salmon Price Reports" differ from (and sometimes are inconsistent with the "Annual Salmon Production Reports" and "Monthly Salmon Price Reports" which are also available at the same website.

ADOR Monthly Salmon Price Reports. Every four months, large Alaska salmon processors (those with sales exceeding 1 million pounds in the previous calendar year) are required to submit salmon price reports to the Alaska Department of Revenue for the following four-month periods: January-April, May-August , and September-December.
The reports include sales volumes and first wholesale values for major salmon product, by area and month. Summaries of the data from these reports, for each four-month period, are available on the Alaska Department of Revenue's Tax Division Reports website at:

http://www.tax.alaska.gov//programs/reports.aspx.

Once at this page, click on "Alaska Salmon Price/Production." Note that these "Monthly Salmon Price Report" differ from (and sometimes are inconsistent with the "Annual Salmon Price Reports" and the "Annual Salmon Production Reports" which are also available at the same website. Data are not reported for product-area-month combinations for which fewer than three processors reported sales.

CFEC Basic Information Tables. The Commercial Fisheries Entry Commission (CFEC) posts "Basic Information Tables" for each Alaska salmon fishery on its website at:

http://www.cfec.state.ak.us/bit/MNUSALM.htm

These tables provide a useful summary of trends since 1975 in each salmon fishery for numbers of permits issued/renewed, numbers of permits fished, total pounds harvested, average pound harvested, gross earnings, average earnings, and average annual permit prices. The most recent data currently available are for 2010.

CFEC Data for Alaska Salmon Harvests 1980-2005. 1980-2005: CFEC Alaska Salmon Summary Data 1980-2005 061113. These are Commercial Fisheries Entry Commission data for Alaska commercial salmon harvest (number of fish, pounds, earnings, and price), by species, for the years 1980-2005. This file was prepared by the Commercial Fisheries Entry Commission on March 31, 2005, in response to a request by Professor Gunnar Knapp of the University of Alaska Anchorage Institute of Social and Economic Research (ISER). The data was provided as an Excel file named SWPrices.xls, containing the worksheet of this file named "Original data." Professor Knapp maintains a copy of the file named "CFEC_Alaska_Salmon_Summary_Data _1980-2005.xls." The data were calculated from CFEC fish ticket database. The harvest and earnings figures include set and drift gill net, test fishing, confiscated and educational permit harvests, and any other harvest where the product was sold.

CFEC Data for Bristol Bay Salmon Harvests 1975-2003. These are Commercial Fisheries Entry Commission data for Bristol Bay commercial salmon harvests for the years 1975-2003, provided by Kurt Iverson, June 9, 2004, as file BBayEarnHarv1.xls. The data were calculated from CFEC fish ticket database. The harvest and earnings figures include set and drift gill net, test fishing, confiscated and educational permit harvests, and any other harvest where the product was sold.

CFEC Permit and Fishing Activity Data. The Commercial Fisheries Entry Commission (CFEC) posts annual data on permit and fishing activity by year, state, census area and Alaska city on its website at:

http://www.cfec.state.ak.us/fishery_statistics/earnings.htm

For each state, census area and city in which permit holders reside, and for each fishery for which residents held permits, data include the number of permits issued, number of permit holders, number of permits with recorded landings, total pounds landed and estimated gross earnings. Earnings data are confidential for fisheries in which fewer than four permit holders in a census area or community had landings.

FAO FishstatJ Database. FAO FishstatJ is software for fishery statistical time series developed by the Food and Agricultural Organization of the United Nations (FAO) Fisheries and Aquaculture Department, based in Rome. The software is designed to be used with global datasets for capture (wild) fisheries catches and aquaculture production, by species, country and year. The software and the global datasets can be downloaded from the FAO Fisheries and Aquaculture Department website at:

http://www.fao.org/fishery/statistics/software/fishstatj/en

NMFS Commercial Fishery Landings Database. The National Marine Fisheries Service (NMFS) Office of Science and Technology maintains an online database of US Commercial Fishery Landings (volume and value) by state, species and year. Customized datasets for Alaska and other states may be downloaded from NMFS Commercial Fishery Landings website at:

http://www.st.nmfs.noaa.gov/st1/commercial/index.html

NMFS Foreign Trade in Fisheries Products Data. The National Marine Fisheries Service posts very detailed data online about U.S. exports and imports of fisheries products at:

http://www.st.nmfs.noaa.gov/st1/trade/

The export data in this report were calculated from the "Monthly Trade Data by Product, Country/Association" option at this website.

NMFS Major Ports Data. The National Marine Fisheries Service publishes an annual report entitled *Fisheries of the United States* which provides a wide variety of useful data on United States fisheries. A regular table in this report (on page 7 in recent years), entitled "Commercial Fishery Landings and Value at Major U.S. Ports," lists the value and volume of landings for the top 50 United States ports (ranked by value). The *Fisheries of the United States* reports are available at:

http://www.st.nmfs.noaa.gov/st1/publications.html

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Alaska License Plate

Prepared for
Pebble Limited Partnership
3201 C Street, Suite 505
Anchorage, Alaska
USA, 99503

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Knight Piésold Ltd.
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VA101-176/57-5

PEBBLE PROJECT

PEBBLE MINE SITE - CLOSURE WATER MANAGEMENT PLAN

Rev	Description	Date
0	Issued in Final	September 21, 2018

Knight Piésold
CONSULTING

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ABBREVIATIONS

Pebble Project	the Project
Bulk TSF	Bulk Tailings Storage Facility
Bulk TSF Main SCP	Bulk TSF Main Embankment Seepage Collection Pond
Main WMP	Main Water Management Pond
NFK	North Fork Koktuli
NTE Level	Not to Exceed Level
OP WMP	Open Pit Water Management Pond
PAG	Potentially Acid Generating
PLP	Pebble Limited Partnership
PMF	Probable Maximum Flood
Pyritic TSF	Pyritic Tailings and Potentially Acid Generating Waste Rock Storage Facility
RO	reverse osmosis
SFK	South Fork Koktuli
SCRP	Seepage Collection Recycle Pond
TDS	Total dissolved solids
tpd	tons per day
TSF	Tailings Storage Facility
UT	Upper Talarik
WSE	water surface elevation

1.0 INTRODUCTION

1.1 PEBBLE PROJECT OVERVIEW

The Pebble Project (the Project) is a proposed mining development of a copper-gold-molybdenum deposit located approximately 238 miles southwest of Anchorage, Alaska, and 17 miles northwest of the village of Iliamna. The deposit is situated on a drainage divide at the headwaters of three waterways, with the Upper Talarik (UT) draining to the east, and the North Fork Koktuli (NFK) and South Fork Koktuli (SFK) draining to the west and southwest, respectively. The Project location and general arrangement for the final year of operations (maximum footprint) are provided on Figure 1.1.

The deposit will be mined by open pit methods feeding an associated process plant with a planned average throughput of 180,000 tons per day (tpd), over an operating life of 20 years. The milling process produces two streams of tailings; a bulk tailings stream and a pyritic tailings stream. The Bulk Tailings Storage Facility (Bulk TSF) will manage non-potentially acid generating tailings (bulk tailings), and the Pyritic Tailings Storage Facility (Pyritic TSF) will manage pyritic tailings, which are Potentially Acid Generating (PAG), and PAG waste rock from the mining activities.

The Project will be closed following operations by decommissioning and reclaiming all Project facilities to a level that achieves long-term stability and compliance with applicable regulatory requirements. The pyritic tailings and PAG waste rock that were managed within the Pyritic TSF during operations will be transferred to the Open Pit and submerged within the Pit Lake. The water level of the Pit Lake will be maintained at a level such that the pit will act as a sink for nearby groundwater (Piteau 2018). Surplus water from the Pit Lake will be treated and discharged. Following the closure of the site, the only facilities remaining will be the reclaimed Bulk TSF and associated seepage collection ponds (including the Bulk TSF Main SCP), a Pit Lake, and a water treatment plant and associated support infrastructure. All other Project facilities will be decommissioned and/or removed and reclaimed.

1.2 SCOPE OF REPORT

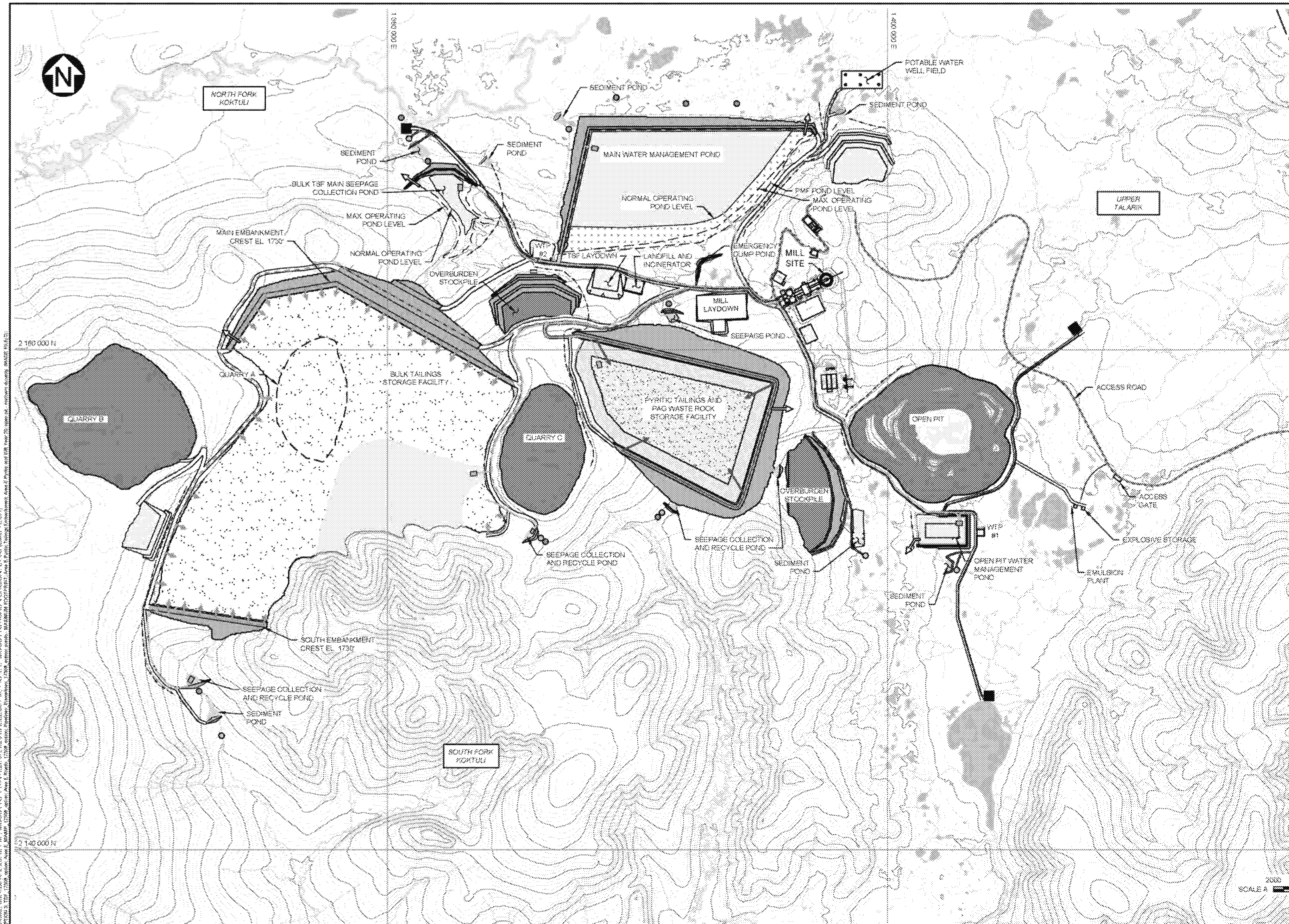
The purpose of this report is to describe the water management plan for the mine site area during closure activities (e.g. while the Project facilities are being decommissioned and reclaimed) and for the long-term steady-state closure conditions (e.g. when the closure of all facilities meet applicable closure criteria and regulations). This closure water management report includes the following:

- A description of how mine affected water and stormwater will be managed at the mine site throughout the closure phases
- Demonstration of the principles for the management of the water levels within the Open Pit, so that there are no uncontrolled releases (surface water or groundwater) from the pit over a full range of potential climate conditions, including prolonged wet periods
- Quantification of the surplus flows available for treatment and discharge, and
- Water quality predictions for the major water management facilities and water treatment plants.

1.3 RELEVANT DOCUMENTS

The following documents are relevant to this Closure Water Management report, and should be reviewed in conjunction with this report:

- Pebble Mine Site – Operations Water Management Plan (KP Reference Number VA101-176/57-4), (KP 2018a)
- Hydrometeorology Report (KP Reference Number VA101-176/57-2), (KP 2018b)
- Pebble Project Supplemental Environmental Baseline Data Report 2004-2012 Chapter 8. Groundwater Hydrology Bristol Bay Drainages. Prepared for The Pebble Partnership (PLP 2015a), and
- Pebble Project Supplemental Environmental Baseline Data Report 2004-2012 Chapter 9. Water Quality Bristol Bay Drainages. Prepared for The Pebble Partnership (PLP 2015b).



LEGEND:

- OPEN PIT
- BULK TAILINGS
- OVERBURDEN STOCKPILE
- GROWTH MEDIUM STOCKPILE
- EMBANKMENT FILL
- POND
- PYRITIC TAILINGS
- PAG WASTE ROCK
- LINER
- MINERAL CLOSING ORDER
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- BULK TAILINGS PIPELINE
- BULK TAILINGS DISCHARGE
- PYRITIC TAILINGS PIPELINE
- PYRITIC TAILINGS DISCHARGE
- WTP POTABLE WATER PIPELINE
- WTP DISCHARGE PIPELINE
- NATURAL GAS PIPELINE (10 inch DIAMETER)
- ROAD
- WTP DISCHARGE POINT
- WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- DIVERSION CHANNEL
- COLLECTION DITCH
- EMERGENCY SPILLWAY

NOTES:

1. COORDINATE GRID IS UTM NAD83, ALASKA STATE PLANES, ZONE 5.
2. CONTOUR INTERVAL IS 25 FEET.
3. DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS NOTED OTHERWISE.
4. OPEN PIT OUTLINE PROVIDED BY PLP, JULY 04, 2018.
5. ACCESS ROAD PROVIDED BY RECON LLC. ROAD CONNECTION TO MILL SITE COMPLETED BY AUSENCO LTD.
6. CONCEPTUAL HAUL, SERVICE, AND ACCESS ROAD CUT AND FILL EXTENTS SHOWN INCLUDE ALLOWANCE FOR BERMS, DITCHES, AND POWER POLES, AS REQUIRED.

SCALE A: 2000 0 2000 4000 6000 8000 10000 ft

PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

GENERAL ARRANGEMENT MAXIMUM FOOTPRINT

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-176/57	5

FIGURE 1.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	21SEP'18	ISSUED WITH REPORT	JRG	MJC	AS1

2.0 HYDROMETEOROLOGICAL CHARACTERISTICS

A summary of the hydrometeorological and groundwater characteristics for the Pebble Project are provided in the Operations Water Management Report (KP 2018a). A full description of the hydrometeorological conditions is provided in the hydrometeorology report (Knight Piésold 2018). A full description of the baseline groundwater conditions is presented in the SEBD Chapter 8 (Groundwater Hydrology) and SEBD Chapter 9 (Water Quality) reports (PLP 2015a; 2015b). A description of the predicted groundwater conditions during and after mine operation is provided in the groundwater modelling report (Piteau 2018). The geochemical parameters used for the development of the water quality model were provided by SRK and are summarized in their geochemical source term report (SRK 2018).

3.0 CLOSURE CONCEPT OVERVIEW

3.1 GENERAL

This section provides an overview of the Project's closure concept as it relates to the water management plan. The closure concepts developed are based on the conceptual mine site layout as presented on Figure 1.1 and in the Operations Water Management Plan (KP 2018a). The overall closure strategy for Project facilities is to decommission and reclaim facilities in a manner that demonstrates compliance with the applicable closure criteria and regulations. This includes leaving the mine site in a stable condition that prevents unnecessary and undue degradation of the land and water resources, and managing the PAG material (pyritic tailings and PAG waste rock) in a manner that reduces the potential generation of acid rock drainage.

The Bulk TSF will be reclaimed by re-sloping and covering the bulk tailings beach surface with a low permeability cover material (for example with compacted overburden or a synthetic liner) and capping it with rockfill sourced from the deconstruction of the Pyritic TSF embankments. A capillary break and growth medium will be placed to minimize contact of precipitation runoff with the bulk tailings. The growth medium, in the context of this report, is assumed to be comprised of native soil material with physical and chemical properties conducive to germinating and sustaining vegetation growth. The low permeability cover materials will reduce infiltration and promote runoff towards the east end of the TSF. Surplus water from the Bulk TSF will be pumped to the Main WMP and then to Water Treatment Plant #2 (WTP#2) during ongoing reclamation of the TSF (Phase 1), and to the Open Pit after the reclamation is complete but water quality is still not acceptable for discharge (Phases 2 and 3). The quality of the supernatant pond water will be monitored following reclamation, and once it has been demonstrated that it meets applicable discharge criteria, surplus water will be discharged through a spillway and conveyed to the NFK catchment.

PAG waste rock and pyritic tailings will be transferred from the Pyritic TSF to the Open Pit. The PAG waste rock will be progressively placed in controlled lifts during Phase 1 closure. The PAG waste rock that is generated during the final year of operations (~27 Mtons) will be stockpiled in the Pyritic TSF such that it is not submerged under pyritic tailings. This rock will be transferred to the Open Pit during the first year of closure, one year prior to any pyritic tailings deposition, to form a base platform of rock that will facilitate the ongoing placement of additional PAG waste rock that will occur concurrent with the placement of pyritic tailings. The pyritic tailings in the Pyritic TSF will be re-slurried and pumped to the Open Pit for sub-aqueous disposal. Backhauling of the PAG waste rock will end approximately 14 years into closure, and the pyritic tailings transfer will end approximately 15 years into closure. Approximately 10 years into closure and the removal of the PAG waste rock and pyritic tailings, select materials from the Pyritic TSF embankments will be used as reclamation materials for the Bulk TSF beach surface. After completion of the Bulk TSF reclamation, the remaining Pyritic TSF embankment materials will be breached and regraded, and the footprint of the Pyritic TSF will be reclaimed.

Partial dewatering of the Open Pit will occur while the PAG waste rock and pyritic tailings are being transferred from the Pyritic TSF to the Open Pit. The water level in the Open Pit will be maintained to allow for controlled placement and management of the PAG waste rock while keeping a water cover over the pyritic tailings. Dewatering of the Open Pit will cease at the end of Phase 1, once the transfer of materials has been completed. The Open Pit will then be allowed to fill with surface water runoff and groundwater to develop a Pit Lake. The Pit Lake water surface will be kept at an elevation to allow shallow groundwater around the pit to continue to discharge into the pit. This elevation has been defined as the Not to Exceed Level (NTE Level), which is at an elevation of 900 fasl (Piteau 2018). The Maximum Management Level (MM Level) is below the NTE Level and has been defined as the maximum water level within the Open Pit required to provide storage for the Probable Maximum Flood (PMF) without encroaching on the NTE Level. The MM Level is approximately 890 fasl. Surplus water from the Open Pit will be pumped and treated to maintain the water surface elevation below the MM Level for the long-term.

WTP#1, located near the Open Pit WMP and used during operations, will be reconfigured to meet the requirements of Open Pit water quality during closure, and will be re-designated Water Treatment Plant #3 (WTP#3).

3.2 PROJECT CLOSURE PHASES

The Project closure has been broken down into four main phases, as shown on Figure 3.1 through Figure 3.5. A timeline of the project phases is shown on Figure 3.6. Approximate timelines have been assigned to each of the closure phases and are based on the results of the water balance and water quality modelling results discussed in this report. The main activities and water management operations for each phase are as follows:

<u>Phase 1: Reclamation of Quarries and Bulk TSF, Backfilling of Open Pit (completed Closure Year 15), Figures 3.1 and 3.2</u>

- Reconfiguration of WTP #1 as WTP #3.
- Reclamation of Quarries B and C, removal of the sediment pond north of Quarry B.
- Transfer of PAG waste rock and Pyritic tailings to the Open Pit.
- Surplus water pumped from the Bulk TSF to the Main WMP throughout Phase 1.
- Reclamation of the Bulk TSF begins in approximately Year 10 to allow for consolidation and differential settlement.
- Pumping of water in the Bulk TSF south and east seepage collection and recycle ponds to the Bulk TSF Main Seepage Control Pond (SCP).
- Pumping of water in the Bulk TSF Main SCP to the Main WMP.
- Pumping of surface runoff from the Pyritic TSF embankment and water collected within the seepage collection ponds to the Main WMP.
- Treatment of surplus water from the Main WMP at WTP #2 and release to the downstream environment.
- Pumping of surplus water from the Open Pit to WTP #3 to maintain the placement of the PAG waste rock in the dry. Treated water released from WTP#3 to the downstream environment.
- Decommissioning and reclamation of the Open Pit Water Management Pond, and direction of surface runoff flows to the downstream environment.
- Reclamation of smaller mine facilities, including the mill site, laydowns, and decommissioned haul roads.

Phase 2: Bulk TSF and Quarries Reclaimed, Backfilling of Open Pit Complete, Reclamation of Pyritic TSF and Main WMP, No Water Treatment (Closure Year 16 through to when the pit is full – approximately Year 20), Figure 3.3

- Decommissioning of WTP #2.
- Decommissioning of the Open Pit clean water diversion channel.
- Reclamation of the Pyritic TSF and associated seepage collection ponds. Subsequent direct discharge of surface water runoff to the downstream environment.
- Reclamation of the Main WMP and discharge of surface water runoff to the downstream environment.
- Pumping of Bulk TSF surplus water to the Open Pit.
- Pumping of water in the Bulk TSF south and east seepage collection and recycle ponds to the Bulk TSF Main SCP.
- Pumping of Bulk TSF Main SCP water to the Open Pit.
- Decommissioning and reclamation of WTP #2 once it has been demonstrated that the surplus water from the reclaimed Pyritic TSF and Main WMP surfaces meets discharge criteria.
- Allowing the Open Pit to fill to the MM Level.
- The basis for the current analysis is that no water will be treated during Phase 2, however an adaptive management strategy would be utilized and water would be directed to WTP#3 for treatment and release if required to maintain downstream flows.

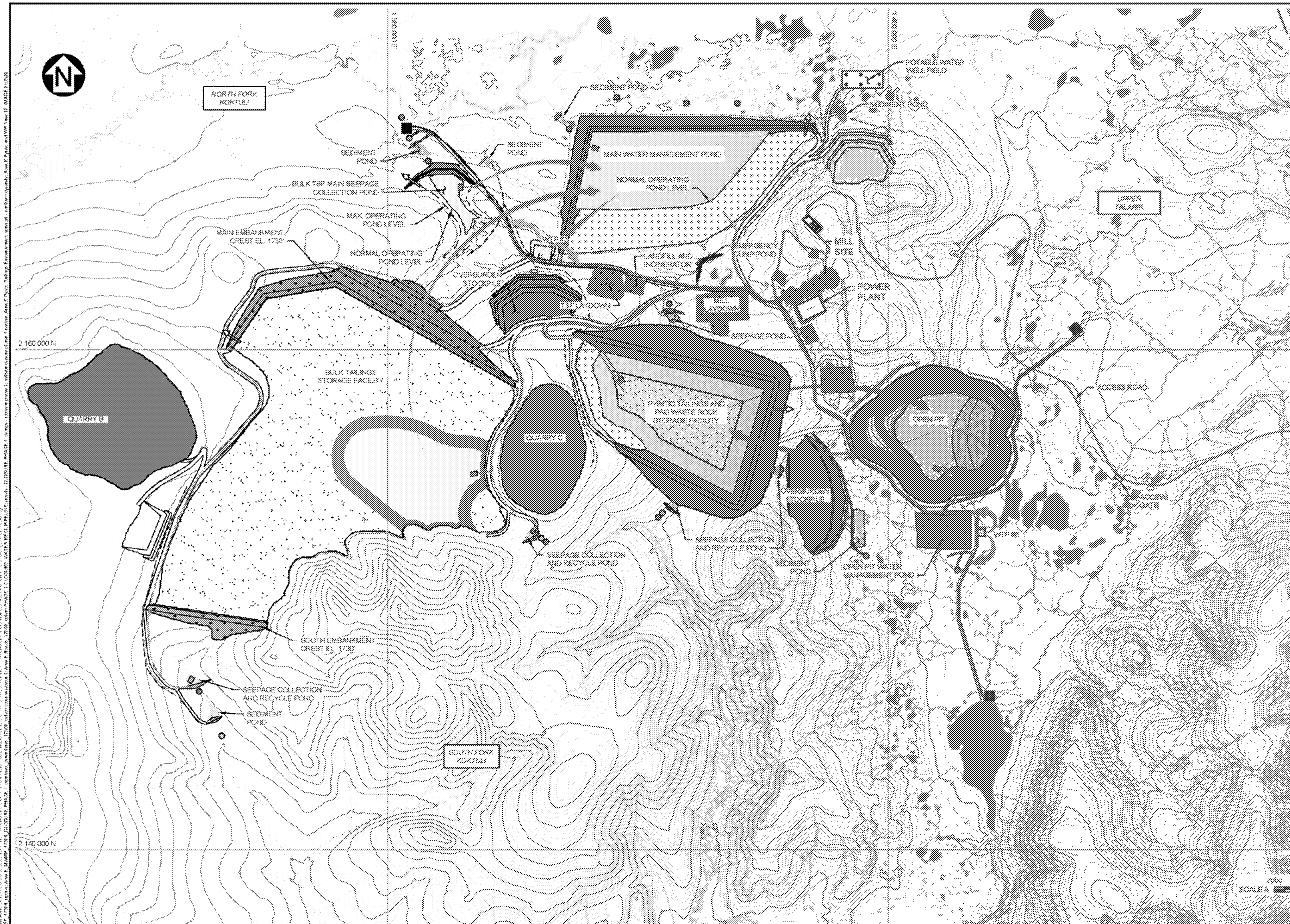
Phase 3: Pyritic TSF and Main WMP Reclaimed, On-Going Treatment Surplus Water within the Open Pit (Year 20 through complete Closure in Year 50), Figure 3.4

- Pumping of Bulk TSF surplus water to the Open Pit.
- Pumping of water from the Bulk TSF south and east seepage collection and recycle ponds to the Bulk TSF Main SCP.
- Pumping of water from the Bulk TSF Main SCP to the Open Pit.
- Maintaining water levels within the Open Pit below the MM Level by treating surplus water from the Open Pit at WTP #3.
- Release of treated water from WTP#3 to the downstream environment.

Phase 4: Post-Closure (long-term conditions), Figure 3.5

- Direct discharge of surface water runoff from the reclaimed Bulk TSF to the NFK catchment. The results of the water quality model, which are discussed in this report, indicate that once the tailings consolidation seepage reaches a minimal rate, which is approximately 50 years after active deposition of bulk tailings into the facility begins, the Bulk TSF supernatant pond will meet the water quality criteria. The water quality of the supernatant pond will be monitored, and once it is demonstrated that it meets the discharge criteria, surplus water from precipitation events will be released through the spillway to the NFK.
- Maintaining water levels within the Open Pit below the MM Level by treating surplus water from the Open Pit at WTP #3.
- Pumping of water at the Bulk TSF south and east seepage collection and recycle ponds to the Bulk TSF Main SCP.
- Pumping Bulk TSF Main SCP flows to WTP#3.

- Decommissioning and reclamation of all freshwater diversions, except for the Bulk TSF Main SCP diversion.
- Release of treated water from WTP #3 to the downstream environment.



LEGEND:

- OPEN PIT
- BULK TAILINGS
- OVERBURDEN STOCKPILE
- GROWTH MEDIUM STOCKPILE
- REVEGETATED - EMBANKMENT FACE
- REVEGETATED - OTHER
- EMBANKMENT FILL
- SEASONAL POND AREA
- POND
- PYRITIC TAILINGS
- PAG WASTE ROCK
- LINER
- MINERAL CLOSING ORDER
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- PYRITIC TAILINGS PIPELINE
- WTP DISCHARGE PIPELINE
- ROAD
- WTP DISCHARGE POINT
- WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- DIVERSION CHANNEL
- COLLECTION DITCH
- EMERGENCY SPILLWAY
- TAILINGS WATER
- RECLAIM WATER
- CONTACT WATER
- TREATED WATER

NOTES:

1. COORDINATE GRID IS UTM NAD83, ALASKA STATE PLANES: ZONE 5
2. CONTOUR INTERVAL IS 25 FEET.
3. DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS NOTED OTHERWISE
4. OPEN PIT OUTLINE PROVIDED BY PLP, JULY 4, 2016.
5. ACCESS ROAD PROVIDED BY REDON LLC. ROAD CONNECTION TO MILL SITE COMPLETED BY AUSENCO LTD.

SCALE A 2000 0 2000 4000 6000 8000 10000 ft

PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

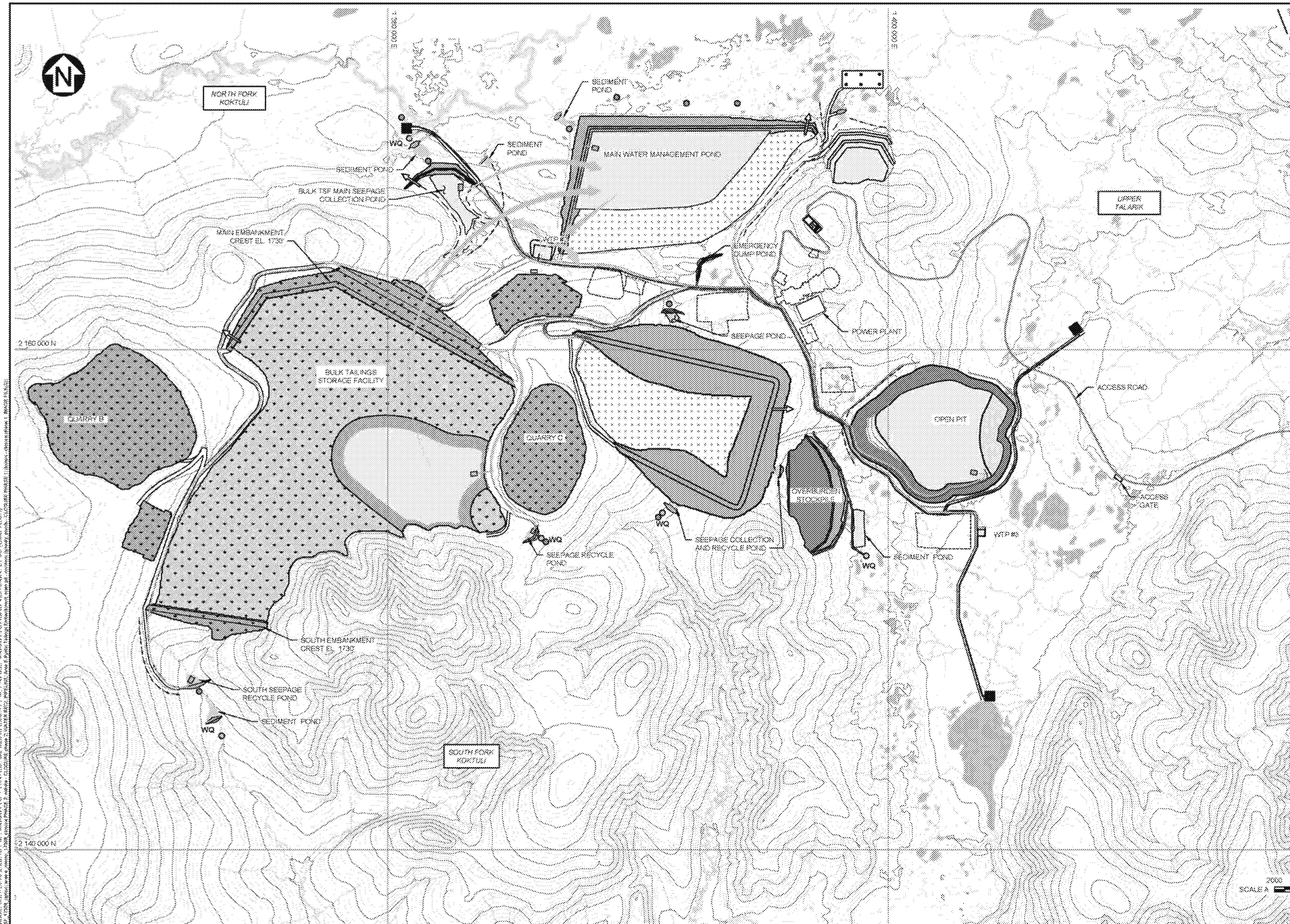
GENERAL ARRANGEMENT
CLOSURE PHASE 1 - YEAR 9

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-176/57	5

FIGURE 3.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	21SEP'16	ISSUED WITH REPORT	JRG	MJC	AS1



LEGEND:

- OPEN PIT
- REVEGETATED - EMBANKMENT FACE
- GROWTH MEDIUM STOCKPILE
- REVEGETATED - BEACH
- SEASONAL WETLAND
- REVEGETATED - OTHER
- POND
- PAG WASTEROCK
- LINER
- MINERAL CLOSING ORDER
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- WTP DISCHARGE PIPELINE
- WTP DISCHARGE POINT
- WQ WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- CLEAN (NON-CONTACT) WATER DIVERSION
- CONTACT WATER DIVERSION
- EMERGENCY SPILLWAY
- PYRITIC TAILINGS PIPELINE
- RECLAIMED FACILITY OUTLINE
- CONTACT WATER
- TREATED WATER

NOTES:

1. COORDINATE GRID IS UTM NAD83, ALASKA STATE PLANES; ZONE 5.
2. CONTOUR INTERVAL IS 25 FEET.
3. DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS NOTED OTHERWISE.
4. OPEN PIT OUTLINE PROVIDED BY PLP, JULY 4, 2016.
5. ACCESS ROAD PROVIDED BY RECON LLC. ROAD CONNECTION TO MILL SITE COMPLETED BY AUSENCO LTD.

SCALE A: 2000 0 2000 4000 6000 8000 10000 ft

PEBBLE LIMITED PARTNERSHIP

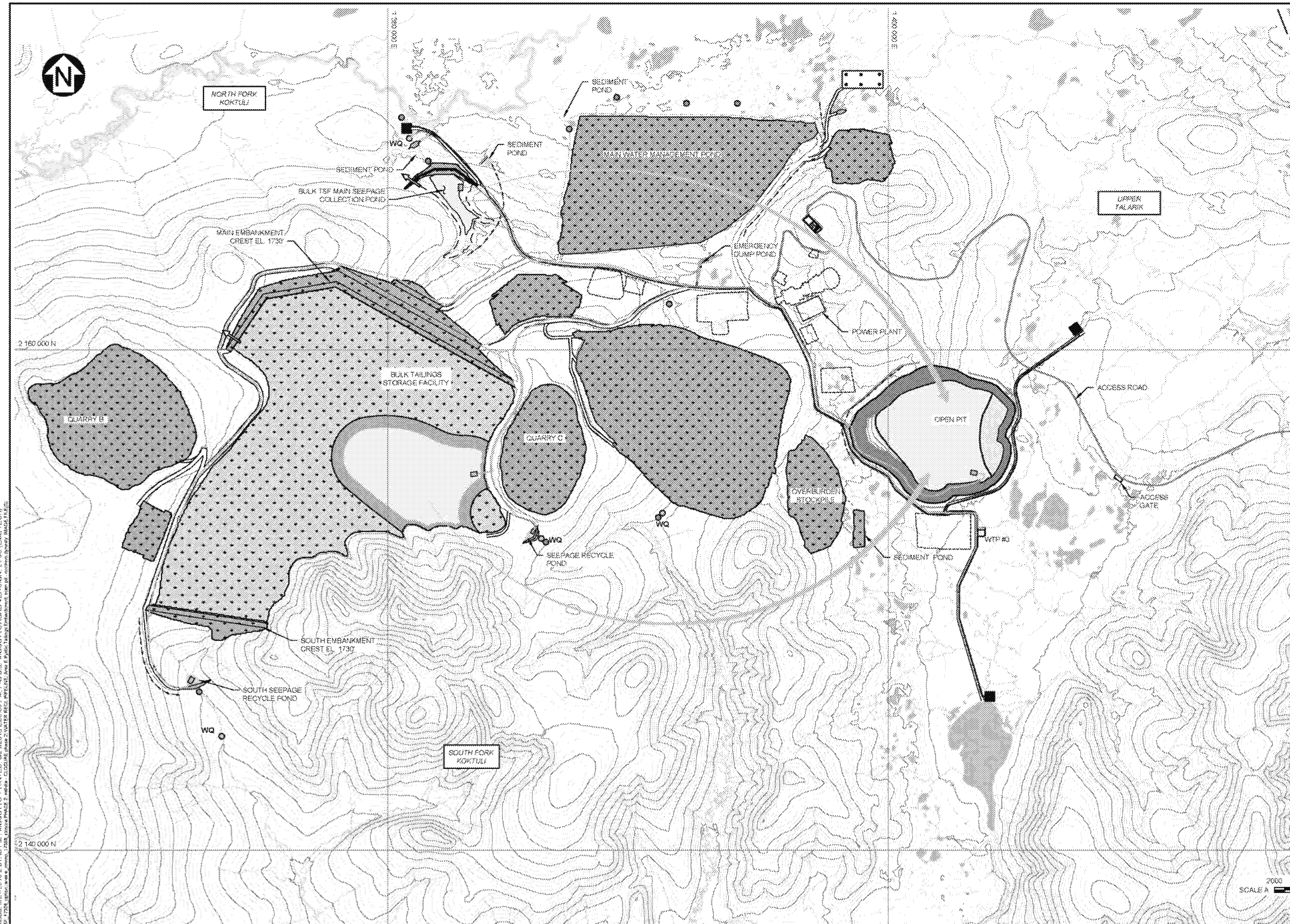
PEBBLE PROJECT

GENERAL ARRANGEMENT
CLOSURE END OF PHASE 1

Knight Piésold CONSULTING

P/A NO.	REF NO.	
VA101-176/57	5	
FIGURE 3.2		REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	21SEP'16	ISSUED WITH REPORT	JRG	MJC	AS1



LEGEND:

- OPEN PIT
- REVEGETATED - EMBANKMENT FACE
- REVEGETATED - BEACH
- SEASONAL WETLAND
- REVEGETATED - OTHER
- POND
- PAG WASTEROCK
- MINERAL CLOSING ORDER
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- WTP DISCHARGE PIPELINE
- WTP DISCHARGE POINT
- WQ WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- CLEAN (NON-CONTACT) WATER DIVERSION
- CONTACT WATER DIVERSION
- EMERGENCY SPILLWAY
- RECLAIMED FACILITY OUTLINE
- CONTACT WATER

NOTES:

1. COORDINATE GRID IS UTM NAD83, ALASKA STATE PLANES: ZONE 5.
2. CONTOUR INTERVAL IS 25 FEET.
3. DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS NOTED OTHERWISE.
4. OPEN PIT OUTLINE PROVIDED BY PLP, JULY 4, 2016.
5. ACCESS ROAD PROVIDED BY RECON LLC. ROAD CONNECTION TO MILL SITE COMPLETED BY AUSENCO LTD.

SCALE A 2000 0 2000 4000 6000 8000 10000 ft

PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

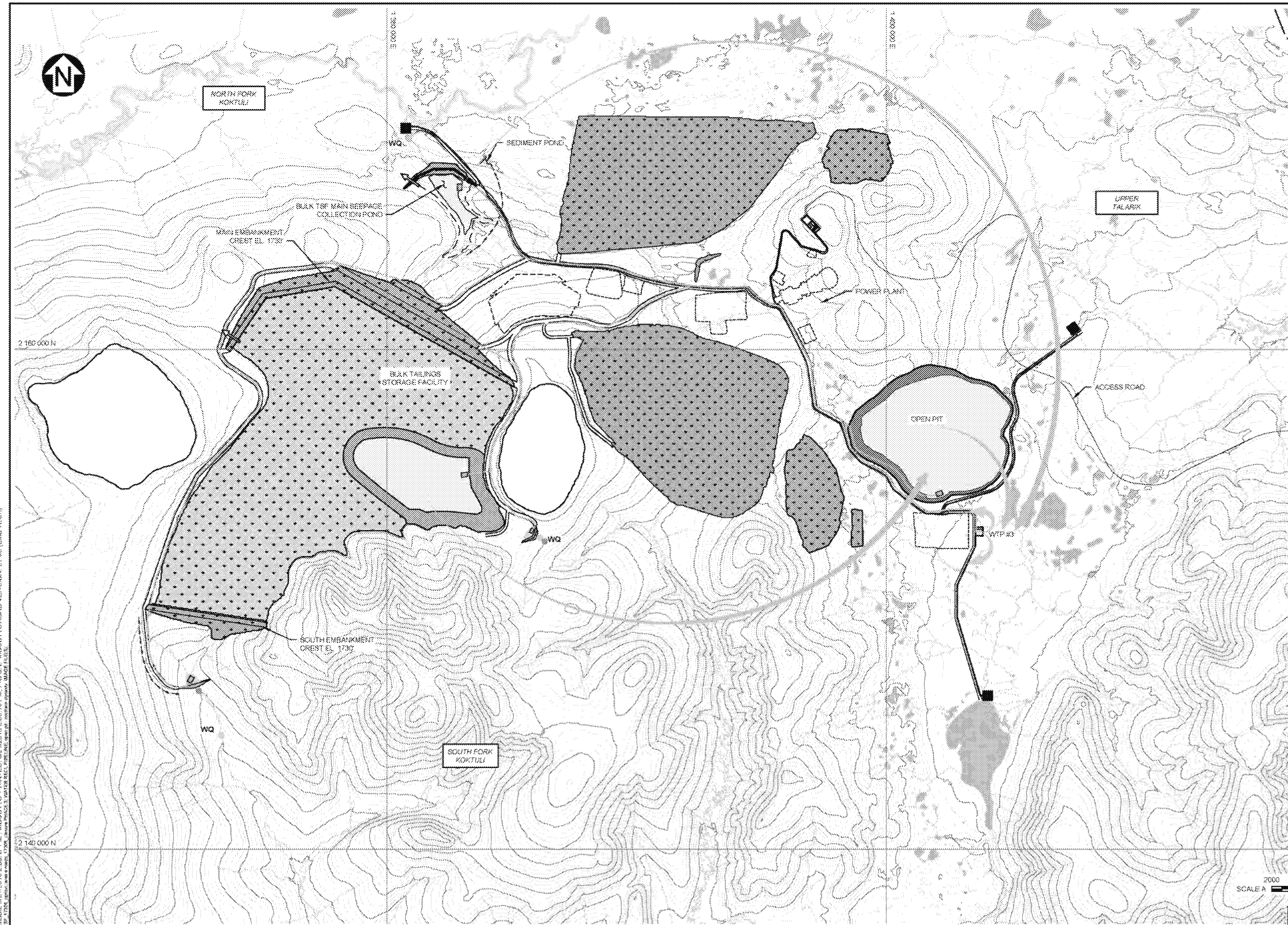
GENERAL ARRANGEMENT CLOSURE END OF PHASE 2

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-176/57	5

FIGURE 3.3 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	21SEP16	ISSUED WITH REPORT	JRG	MJC	AS1



NOTES:

1. COORDINATE GRID IS UTM NAD83, ALASKA STATE PLANES, ZONE 5
2. CONTOUR INTERVAL IS 25 FEET
3. DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS NOTED OTHERWISE.
4. OPEN PIT OUTLINE PROVIDED BY PLP, JULY 4, 2018

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	21SEP18	ISSUED WITH REPORT	JRG	MJC	AS1

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PEBBLE PROJECT

GENERAL ARRANGEMENT
CLOSURE PHASE 3

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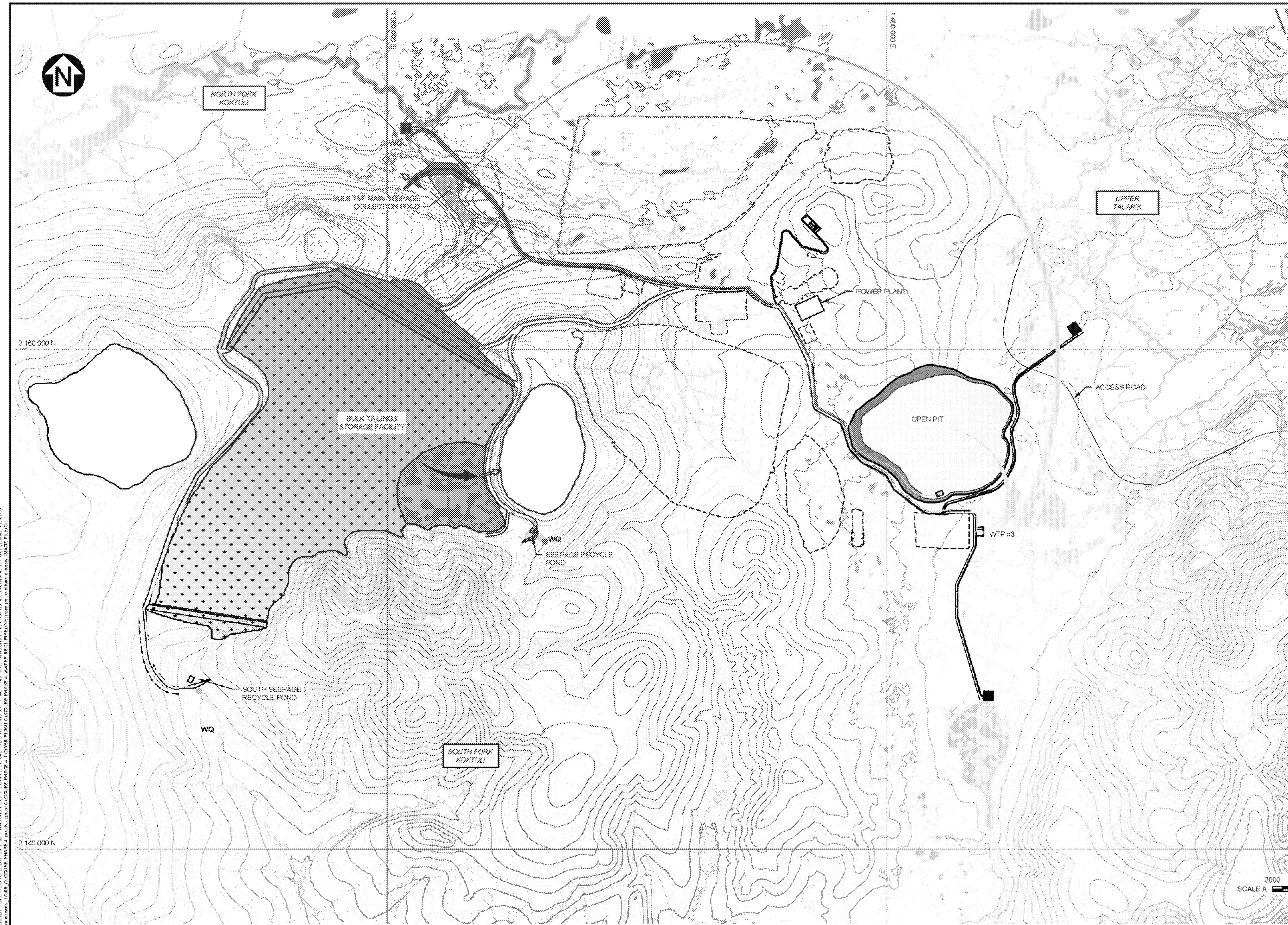
P/A NO. VA101-176/57 | REF NO. 5

FIGURE 3.4 | REV 0



LEGEND:

- OPEN PIT
- REVEGETATED - EMBANKMENT FACE
- REVEGETATED - BEACH
- SEASONAL WETLAND
- REVEGETATED - OTHER
- POND
- MINERAL CLOSING ORDER
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- WTP DISCHARGE PIPELINE
- WTP DISCHARGE POINT
- WQ WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- CLEAN (NON-CONTACT) WATER DIVERSION
- EMERGENCY SPILLWAY
- RECLAIMED FACILITY OUTLINE
- CONTACT WATER
- TREATED WATER
- CLEAN WATER

NOTES:

1. COORDINATE GRID IS UTM NAD83, ALASKA STATE PLANES, ZONE 5
2. CONTOUR INTERVAL IS 25 FEET.
3. DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS NOTED OTHERWISE.
4. OPEN PIT OUTLINE PROVIDED BY PLP, JULY 4, 2018

SCALE A: 2000 0 2000 4000 6000 8000 10000 ft

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	21SEP18	ISSUED WITH REPORT	JRG	MJC	AS1

PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

GENERAL ARRANGEMENT
POST CLOSURE PHASE 4

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P/A NO. VA101-176/57 | REF NO. 5

FIGURE 3.5 | REV 0

Facility	Closure Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Activity	Phase 1															Phase 2 (Note 1)				
Bulk TSF	Consolidation seepage reporting to Bulk TSF supernatant pond																				
	Bulk TSF pond water pumped to Main WMP																				
	Regrading and capping of tailings surface																				
	Overburden placed and seeded and vegetation established																				
	Bulk TSF pond water pumped to Open Pit																				
	Bulk TSF pond water released to environment through spillway																				
	Bulk TSF seepage (via the Bulk TSF Main SCP) pumped to Main WMP																				
	Bulk TSF seepage (via the Bulk TSF Main SCP) pumped to Open Pit																				
	Bulk TSF seepage (via the Bulk TSF Main SCP) pumped to WTP#3																				
Open Pit	Backhauling of PAG WR																				
	Re-slurry of Pyritic Tailings																				
	Pumping to WTP#3 (for controlled placement of PAG WR)																				
	Pit Filling to Maximum Management (MM) Level																				
	Pumping to WTP#3 (to maintain WSE below MM Level)																				
Pyritic TSF	Dewatering (Tailing re-slurry to Open Pit)																				
	Embankment Runoff and seepage to Main WMP																				
	Reclamation Activities																				
Water Treatment and Monitoring	WTP#2 Treating and releasing water to downstream environment																				
	WTP#3 Treating and releasing water to downstream environment																				
	Water Quality Monitoring - Bulk TSF																				
	Water Quality Monitoring - Pyritic TSF and Main WMP																				

Facility	Closure Year:	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	55+
	Activity	Phase 3 (Note 1)																														Phase 4					
Bulk TSF	Consolidation seepage reporting to Bulk TSF supernatant pond																																				
	Bulk TSF pond water pumped to Main WMP																																				
	Regrading and capping of tailings surface																																				
	Overburden placed and seeded and vegetation established																																				
	Bulk TSF pond water pumped to Open Pit																																				
	Bulk TSF pond water released to environment through spillway																																				
	Bulk TSF seepage (via the Bulk TSF Main SCP) pumped to Main WMP																																				
	Bulk TSF seepage (via the Bulk TSF Main SCP) pumped to Open Pit																																				
	Bulk TSF seepage (via the Bulk TSF Main SCP) pumped to WTP#3																																				
Open Pit	Backhauling of PAG WR																																				
	Re-slurry of Pyritic Tailings																																				
	Pumping to WTP#3 (for controlled placement of PAG WR)																																				
	Pit Filling to Maximum Management (MM) Level																																				
	Pumping to WTP#3 (to maintain WSE below MM Level)																																				
Pyritic TSF	Dewatering (Tailing re-slurry to Open Pit)																																				
	Embankment Runoff and seepage to Main WMP																																				
	Reclamation Activities																																				
Water Treatment and Monitoring	WTP#2 Treating and releasing water to downstream environment																																				
	WTP#3 Treating and releasing water to downstream environment																																				
	Water Quality Monitoring - Bulk TSF																																				
	Water Quality Monitoring - Pyritic TSF and Main WMP																																				

NOTES:

1. THE END OF PHASE 2 AND BEGINNING OF PHASE 3 ARE DEPENDENT ON WHEN THE OPEN PIT FILLS TO THE LEVEL THAT REQUIRES PUMPING TO WTP#3 TO MAINTAIN THE WSE BELOW THE MM LEVEL

0	21SEP'18	ISSUED WITH REPORT	MAP	AS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

TIMELINE OUTLINING CLOSURE PHASES

Knight Piésold CONSULTING

P/A NO. VA101-176/57 | REF. NO. 5

FIGURE 3.6 | REV 0

4.0 CLOSURE WATER MANAGEMENT PLAN

4.1 GENERAL

The operations water management plan (KP, 2018a) provides the characterization of the groundwater and surface water runoff within the Project mine site footprint. A brief summary of the waters that will be managed at closure is provided as follows:

- Fresh water: water that has not come into direct contact with un-reclaimed areas or is otherwise not mine affected, and therefore may be discharged to the environment without treatment in the water treatment plants. These flows are expected to have similar runoff patterns to the pre-mine and operations hydrographs, with high flows occurring during the spring snowmelt season and fall rainy season, and low flows occurring during the late summer period. Minimal flows are expected during the winter when precipitation will mostly fall as snow.
- Stormwater: runoff from un-reclaimed areas that only requires treatment for sediment to meet discharge water quality standards prior to discharge to the environment. Stormwater is defined under EPA discharge regulation 40 CFR 122.26 (b) (13) as "Stormwater runoff, snowmelt runoff, and surface runoff and drainage". Stormwater will be discharged under general Alaska Pollutant Discharge Elimination System (APDES) Stormwater Permits.
- Mine-affected water: water affected by the former mining operation that requires treatment at the water treatment plants to meet discharge water quality standards prior to discharge to the environment. Mine-affected water is anticipated to include, but may not be limited to, water in the Bulk TSF, the Pyritic TSF, the Main WMP, the Open Pit WMP, and the Open Pit.

The water management plan for the above-defined water sources and each phase of closure is described in the following sections.

4.2 FRESH WATER DIVERSION CHANNELS

Fresh water diversion channels are proposed for operations to collect and convey surface water runoff from undisturbed ground and directly discharge it to downstream waterways. The diversion channels from operations will be maintained while the facilities are being reclaimed. Once a facility has been reclaimed and surface water runoff meets the required closure criteria, the associated diversion channels will be decommissioned so that the drainage pathways are returned, as much as possible, to pre-project conditions.

4.3 BULK TAILINGS STORAGE FACILITY

Active reclamation of the Bulk TSF will begin in Year 10 of closure during Phase 1. The delay is to allow for the majority of the tailings consolidation and differential settlement to occur before grading. Surplus water collected in the TSF supernatant pond will be pumped to the Main WMP during Phase 1 of closure, and to the Open Pit in Phases 2 and 3.

Seepage water will be collected in the South and East Seepage Collection Recycle Ponds (SCRP) and the Bulk TSF Main SCP. The flows from the South and East SCRPs will be pumped to the Bulk TSF Main SCP, and then will be pumped to the Main WMP during Phase 1, to the Open Pit during Phase 2 while the Open Pit is filling, and then directly to WTP#3 during Phases 3 and 4.

The Bulk TSF will be deemed fully reclaimed once the supernatant pond water meets discharge water quality criteria, which corresponds to the start of Phase 4 for the purposes of the closure water management plan. As the tailings mass consolidates, water that was previously trapped within the interstitial spaces of the tailings solids is assumed to be released to the supernatant pond. The water quality of the supernatant pond will be monitored, and once it meets discharge water quality criteria, surplus water from precipitation events will be discharged from the Bulk TSF through an operating spillway to the downstream NFK catchment. The spillway will be constructed to pass the PMF from the facility.

Water that infiltrates the low permeability cover over the bulk tailings beach will report as seepage from the Bulk TSF and will be collected in the Bulk TSF Main SCP and the South and East SCRPs. The water collected within the ponds will be monitored for quality and these ponds will remain active until discharge water quality criteria are met. The water quality modelling results presented in this report indicate that, under the current assumptions, seepage water from the Bulk TSF will require treatment for the long-term.

4.4 PYRITIC TAILINGS AND PAG WASTE ROCK STORAGE FACILITY

PAG waste rock and pyritic tailings from the Pyritic TSF will be transferred to the Open Pit during Phase 1 of closure. The PAG waste rock will be progressively placed within the Open Pit in controlled lifts, starting one year prior to any pyritic tailings deposition. Additional PAG waste rock will be transferred as it becomes exposed within the Pyritic TSF while the pyritic tailings are being re-slurried and transferred to the Open Pit. Water stored within the Pyritic TSF, including the supernatant pond accumulated during operations, water trapped within the tailings voids, direct pond precipitation, and surface runoff during the closure phase, will be used to re-slurry the tailings. Additional water will be reclaimed from the Open Pit to support the re-slurring activities, as required.

Seepage collection and recycle ponds located downstream of the Pyritic TSF to the north, south, and east will remain active while the pyritic tailings and PAG waste rock are being transferred to the Open Pit. Seepage flows to the south and east will be pumped back to the TSF, as required, and seepage flows to the north will be pumped to the Main WMP. These ponds will be removed and the areas reclaimed during Phase 2.

Select embankment materials will be used during the later years of Phase 1 as reclamation materials for the Bulk TSF. After the removal of the pyritic tailings and PAG waste rock, the remaining Pyritic TSF embankment materials will be breached, the liner and impacted materials will be removed, and the surface will be re-graded and capped with a growth medium. Surface water runoff will then be discharged to the downstream NFK catchment.

4.5 MAIN WATER MANAGEMENT POND

The Main WMP will provide water storage surge capacity for the mine site during Phase 1 of closure. The Main WMP will manage water pumped from the Bulk TSF supernatant pond, water from the Bulk TSF SCP, and runoff from the Pyritic TSF main embankment. Surplus water in the Main WMP will be treated for release at WTP #2. Once the Main WMP is reclaimed, the embankments will be breached, the liner and impacted materials will be removed, and the surface will be re-graded and capped with a growth medium. Surface water runoff will then be discharged downstream in the NFK catchment.

4.6 OPEN PIT

The Open Pit WMP and its associated sediment pond will be removed and the areas will be reclaimed during Phase 1 of closure. While the PAG waste rock and pyritic tailings are being transferred to the Open Pit during Phase 1, partial dewatering of the Open Pit will occur to allow for controlled placement and management of the PAG waste rock while keeping a water cover over the pyritic tailings. Water from the Open Pit will be pumped to the Pyritic TSF to support the re-slurry of the pyritic tailings, as required.

After transfer of the PAG waste rock and pyritic tailings from the Pyritic TSF to the Open Pit is completed during Phase 1, dewatering of the Open Pit will cease and the pit will be allowed to fill with surface water runoff and groundwater inflows. Surplus water from the Bulk TSF Main SCP and Bulk TSF supernatant pond will be pumped to the Open Pit during this filling stage (Phase 2), and the Open Pit Fresh Water Diversion Channel will be decommissioned to reduce the time to fill the pit. Once the Open Pit has reached the MM Level, signifying the start of Phase 3 (approximately 20 years into closure based on the water balance model results), Open Pit surplus water will be treated at WTP#3 and released to the downstream environment.

In Phase 3, the surplus water from the Bulk TSF supernatant pond will be pumped to the Open Pit while water from the Bulk TSF Main SCP will be pumped directly to WTP#3 for treatment and release. Throughout closure, the water level within the Open Pit will be maintained at or below the MM Level, thereby allowing shallow groundwater around the pit to continue to discharge into the pit (Piteau 2018). The water level will be maintained by pumping surplus water from the Open Pit to WTP#3 to be treated and released long-term.

4.7 QUARRIES B AND C

Quarry locations B and C will be actively reclaimed during Phase 1 of closure. The reclaimed quarries will be sloped to promote fresh water runoff away from the Bulk TSF. This freshwater will be directed to the downstream environment. During Phase 2, after the Pyritic TSF and diversion channels are reclaimed, the freshwater runoff will flow directly towards NFK.

The sediment pond located to the north west of Quarry B will be reclaimed during Phase 1 of closure, after the reclamation of the quarry is complete.

4.8 WATER TREATMENT PLANTS

Two water treatment plants will be in operation at various stages during closure. WTP #2, located near Main WMP, will treat water sourced from Main WMP during Phase 1. WTP #3 will treat surplus water from the Open Pit while the PAG waste rock and pyritic tailings are being transferred (Phase 1), while the surplus water from the Bulk TSF supernatant pond and Bulk TSF Main SCP are collected within the Open Pit (Phase 3), and as required to maintain the water level below the NTE Level for the long-term (Phase 4). Surplus water from the Bulk TSF Main SCP will also be directed to WTP#3 during Phase 4 and for the long-term. Reject flows from WTP #2 and WTP #3 will be directed to the Open Pit during all phases of closure and will be piped to depth.

5.0 CLOSURE WATER BALANCE MODEL

5.1 INTRODUCTION

A water balance was developed for the closure period of the Project. The water balance is comprised of three modules: the Watershed Module, the Groundwater Module, and the Mine Plan Module. This section describes the Mine Plan Module (the model) and presents the associated inputs, assumptions, and results. The model simulates the movement of water within the mine site, and uses inputs from the Watershed Module and the Groundwater Module. The model estimates the amount of water to manage at the mine site during the closure periods of the mine under a full range of historical climate conditions.

5.2 INPUTS AND ASSUMPTIONS

The model was completed in monthly increments using GoldSim® software, and was based on the conceptual closure footprints shown on Figure 3.1 through Figure 3.5, and on the closure water management strategy described within this report. The water management strategy incorporated into the Mine Plan Module is shown as flow schematics per closure phase on Figures A.1 through A.4 in Appendix A. The average annual flows per closure phase are shown in Table A.2 through A.5 in Appendix A for relatively dry, average, and relatively wet climate conditions.

Climate variability was incorporated into the model by utilizing the 76-year synthetic time-series of monthly temperature and precipitation values developed for the Project site. The time-series data were incrementally stepped by year within the model, for a 76 year closure period that covered all four phases of the closure, thereby preserving the inherent cyclical nature of the climate record. The model was run for 76 different realizations, thereby generating 76 unique results of water flow and storage for each month of each year of the modeled closure activities.

Additional inputs and assumptions for the model include:

- The pyritic tailings has an SG of 2.9 (Ausenco 2017) and an assumed dry density of 100 pcf.
- The pyritic tailings is re-slurried at a solids content of 25% by weight, starting in the second year of closure, and is transferred by three pumps, each with a capacity of 6,000 gpm.
- Water for pyritic tailings re-slurry activities comes from the following sources, based on availability and in order of priority:
  1. Pyritic TSF, and
  2. Open Pit.
- A total of approximately 160 million short tons of PAG waste rock that is stored in the Pyritic TSF during operations will be transferred to the Open Pit at closure (approximate volume of 2.7 billion ft^3 assuming a density of 120 pcf). The PAG WR transfer begins at the start of closure.
- Groundwater inflow to the Open Pit is at a rate of 2,700 gpm (6 cfs) when the Open Pit is empty and 1,300 gpm (3 cfs) when the Open Pit is at the MM Level. Between these two values it is linearly interpolated based on the volume of water in the Open Pit.
- The flow-through rate of the Bulk TSF main embankment is estimated to occur at constant rates of 8.0 cfs during operations (KP 2018c) and 1.2 cfs during post-closure phases. It is assumed that the seepage rate decreases linearly over a 30 year period as the bulk tailings are drained.

- The dry density of the bulk tailings is estimated to be 90 pcf at the end of operations, and increasing to 95 pcf 50 years after bulk tailings have stopped being deposited in the Bulk TSF.
- The increase in dry density is due to the consolidation of the bulk tailings that results from the release of pore water from the tailings mass. This released water was previously trapped within the void spaces between the tailings particles. It was assumed that all of the bulk tailings consolidation seepage water will report to the Bulk TSF supernatant pond, therefore requiring this water to be managed even after the Bulk TSF beaches have been reclaimed. The consolidation seepage to the supernatant pond is estimated to be approximately 6 cfs at the start of closure, to decrease to approximately 3 cfs five years into closure, and to be essentially zero 50 years after the end of operations. These seepage rates were estimated on the basis of consolidation modeling previously completed for the project, with consideration of changes in tailings grind and density.
- Cooling water required by the power plant is a negligible flow and is not included in the closure or post-closure water balance model flows.
- Water associated with dust control during closure is a negligible flow and is not included in the closure or post-closure water balance model flows.
- WTP#2, which is located near the mill, has a maximum treatment rate of 41 cfs, which is provided by four trains of equal treatment capacity. WTP #2 is estimated to have a reverse osmosis (RO) reject rate of 2.3% of the inflow rate to WTP#2 (HDR 2018). The reject sludge and reject flow from WTP#2 will be directed to the Open Pit during closure.
- WTP#3, which is located near the Open Pit, becomes active during the closure phases. It has a maximum treatment rate of 49 cfs, which is provided by three trains of equal capacity and allows for a maximum treatment capacity of 38 cfs from the Open Pit and 11 cfs from the Bulk TSF Main WMP. WTP #3 is assumed to have a RO reject rate of 2.3% of the inflow rate to WTP#3. The reject sludge and reject flow from WTP#3 will be directed to the Open Pit during closure.

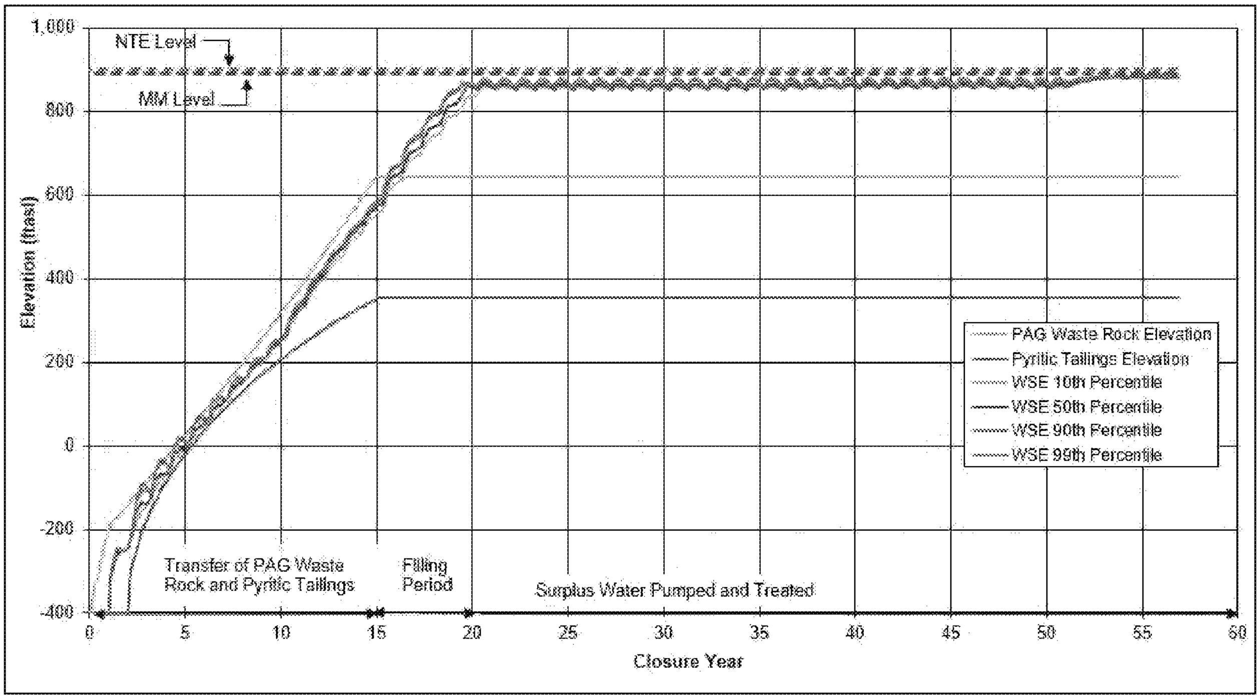
5.3 MINE PLAN MODULE WATER BALANCE RESULTS

The Mine Plan Module results for each phase of closure are described in the sections below.

5.3.1 WATER VOLUMES IN THE PIT LAKE

Estimated water surface elevations (WSE) for the Open Pit, for all phases closure, are shown on Figure 5.1 in terms of the 10th, 50th, 90th, and 99th percentile values. The approximate elevations of the PAG waste rock and pyritic tailings are also shown on this figure. These results indicate that the Open Pit will operate below the MM level at all times during closure. The water balance results also indicate that during Phases 1 and 2 of closure, a dewatering rate of 20 cfs will maintain the water level below the elevation of the PAG waste rock for all months, for more than half of the modeled realizations. The other half of the realizations did indicate some inundation of the PAG waste rock during periods of high runoff. These periods were limited to the spring freshet, with a maximum time of inundation of 6 months. This situation was deemed to be acceptable because the estimated amount of PAG waste rock that needs to be hauled to the Open Pit each year can be moved within 6 months, using the available mine fleet.

The water balance model indicates that it will take approximately 19 to 21 years to fill the Open Pit to the maximum management (MM) level, depending on the climatic conditions. Furthermore, under steady state conditions (Phase 4), the average annual surplus from the Open Pit is modeled to be approximately 3 cfs.



NOTES:

1. NTE LEVEL: NOT TO EXCEED LEVEL.
2. MM LEVEL: MAXIMUM MANAGEMENT LEVEL.

Figure 5.1 Open Pit Water Surface Elevations

5.3.2 MAIN WATER MANAGEMENT POND VOLUMES

The estimated 10th, 50th, 90th, and 99th percentile pond volumes for the Main WMP are shown on Figure 5.2, for Phase 1 through Phase 4 of closure. These results indicate that the Main WMP has the capacity to manage the surplus water from the mine site during closure Phase 1 and Phase 2, when the Bulk TSF and Pyritic TSF are being reclaimed. The water within the Main WMP will operate below the maximum operating pond capacity at all times.

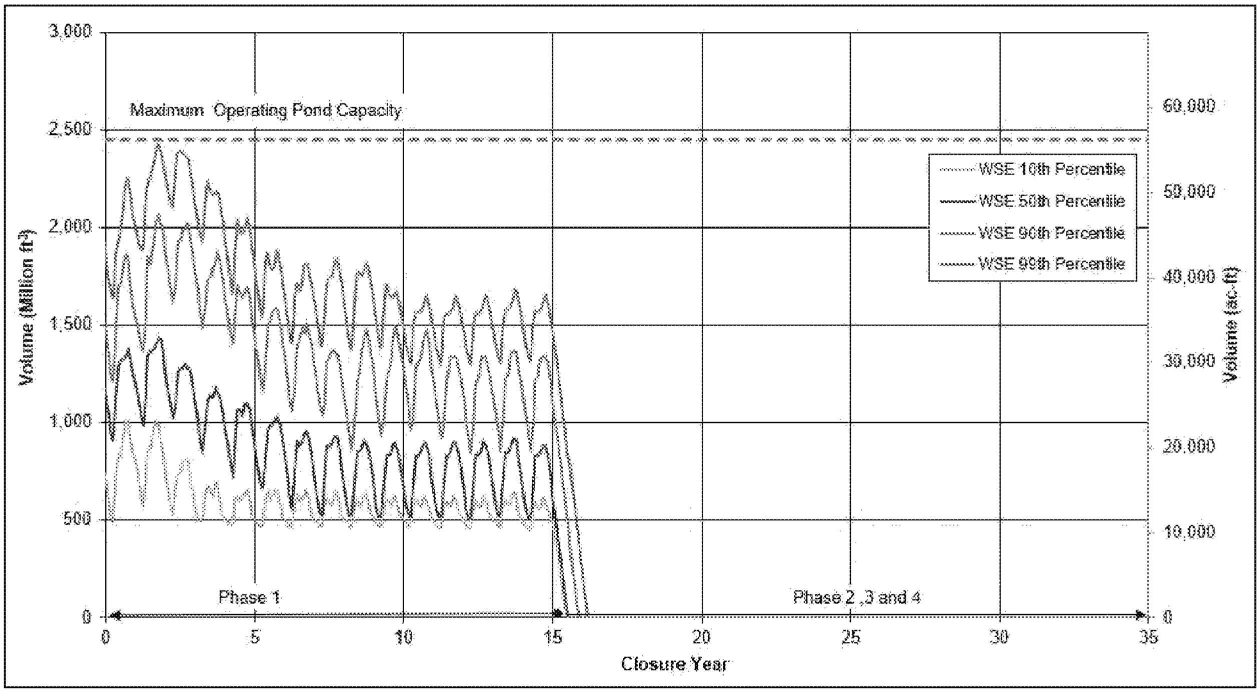


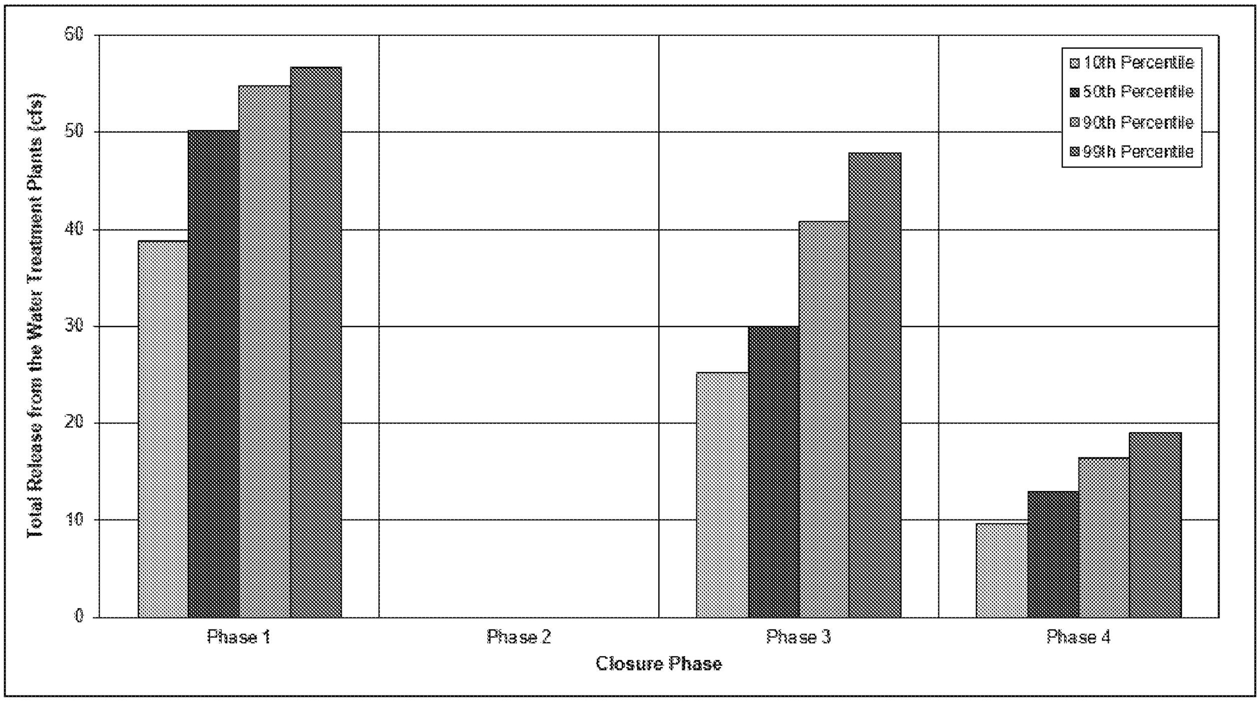
Figure 5.2 Main WMP Volumes

5.3.3 TOTAL RELEASE FROM THE WATER TREATMENT PLANTS

The total flows released downstream of the Project mine site are a combination of fresh water from the diversion channels, surface runoff from reclaimed facilities, and treated water from the water treatment plants. The water treatment plant flows are expected to vary based on the amount of water captured at the mine site depending on the climate variability, whereas the flows from the fresh water diversions and reclaimed facilities are expected to vary according to natural flow patterns (which in turn are linked to climate variability).

The 1st, 10th, 50th, 90th, and 99th percentile values of total water released from the water treatment plants are summarized on an annual average basis for closure Phases 1 through 4 in Table 5.1, and for the 10th, 50th, 90th, and 90th percentile values on an annual basis on Figure 5.3. These results indicate that the total amount of water treatment required is greatest during the early phases of closure, when the mine site footprint is larger and lowest during Phase 4, once all of the mine facilities are reclaimed and the only water being treated is the surplus that is pumped from the Open Pit to maintain the water levels.

The total flow releases from the water treatment plants can vary from a high of 58 cfs during Phase 1 (99th percentile results) to a low of 3 cfs during the final Phase 4 (1st percentile results). There are no releases from the water treatment plants during Phase 2, which is after the PAG waste rock and pyritic tailings transfer to the Open Pit is complete, but before the Open Pit is full. Phase 2 occurs for an approximate 5 year period, and during this period the total captured surface runoff, direct pond precipitation, and groundwater flow rate is approximately 40 cfs under average climate conditions.



NOTES:

1. WATER TREATMENT PLANT RELEASES INCLUDE THOSE FROM WTP#2 AND WTP#3 DURING CLOSURE PHASES.

Figure 5.3 Average Annual Flow from Water Treatment Plants

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TABLE 5.1

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

CLIMATE VARIABILITY CLOSURE WATER BALANCE
TOTAL WATER TREATMENT PLANT DISCHARGE

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Closure Phase 1

Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
Jan	16	23	46	53	55
Feb	15	21	45	51	55
Mar	15	21	37	49	55
Apr	15	22	40	51	56
May	33	51	55	57	57
Jun	24	54	57	57	58
Jul	17	51	56	57	57
Aug	32	52	56	57	57
Sep	34	53	56	57	58
Oct	15	49	55	56	57
Nov	15	44	53	56	57
Dec	15	25	47	55	56
Annual Average	21	39	50	55	57

Closure Phase 2

Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0
Annual Average	0	0	0	0	0

Closure Phase 3

Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
Jan	19	19	23	29	48
Feb	20	20	20	29	48
Mar	19	19	19	29	48
Apr	21	22	26	29	48
May	29	29	30	41	48
Jun	26	29	40	48	48
Jul	22	29	34	48	48
Aug	29	29	36	48	48
Sep	27	29	39	48	48
Oct	24	29	34	48	48
Nov	20	27	29	48	48
Dec	19	19	29	45	48
Annual Average	23	25	30	41	48

Closure Phase 4

Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
Jan	3	4	7	10	19
Feb	3	4	7	9	19
Mar	4	4	7	9	18
Apr	5	7	11	16	19
May	13	17	18	19	20
Jun	6	14	18	19	20
Jul	6	14	18	20	20
Aug	11	15	18	20	20
Sep	10	14	18	20	20
Oct	6	10	17	20	20
Nov	5	8	9	20	20
Dec	4	5	8	16	17
Annual Average	6	10	13	16	19

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NOTES:

1. TOTAL RELEASE FROM WTP IS THE SUM OF THE FLOWS AVAILABLE FOR RELEASE FROM WTP#2 AND WTP#3 DURING CLOSURE PHASES.

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6.0 CLOSURE WATER QUALITY MODEL

6.1 GENERAL

A water quality model (WQ model) was developed to predict the water quality during the various closure phases using a mass balance approach. Results of the WQ model were used to determine the requirements of the water treatment plants (WTP) and to inform water management decisions. Water quality predictions were developed for the following nodes:

- Bulk TSF (all closure phases)
- Bulk TSF Main SCP (all closure phases)
- Pyritic TSF (Phase 1)
- Main WMP (Phase 1)
- Open Pit Lake (all closure phases
- Inflow to WTP#2 (Phase 1), and,
- Inflow to WTP#3 (Phases 1, 3 and 4).

Water collected within the mine site footprint that does not meet discharge water quality criteria will be treated in water treatment plants prior to discharge to the environment. The water treatment plants will be designed to meet the specified discharge water quality criteria, which are summarized in Table 6.1.

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TABLE 6.1

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

WATER QUALITY CRITERIA IN RECEIVING WATER BODY

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Parameter	Units	Estimated Limits & Basis	
		Most Stringent	Basis
Aluminum (total)	ug/L	87	WQBEL-ALC
Antimony (total)	ug/L	6	WQBEL-DW
Arsenic (total)	ug/L	10	WQBEL-DW
Barium (total)	ug/L	2000	WQBEL-HH
Beryllium (total)	ug/L	4	WQBEL-HH
Boron (total)	ug/L	750	WQBEL-HH
Cadmium (H) (total)	ug/L	0.08	WQBEL-ALC
Chloride	ug/L	230000	WQBEL-ALC
Total Residual Chlorine	ug/L	11	WQBEL-ALC
Chromium (total)	ug/L	100	WQBEL-DW
Chromium III (H) (total)	ug/L	19.18	WQBEL-ALC
Chromium VI (dissolved)	ug/L	11	WQBEL-ALC
Cobalt (total)	ug/L	50	WQBEL-IR
Copper (H) (total)	ug/L	2.19	WQBEL-ALC
Cyanide (WAD)	ug/L	5.2	WQBEL-ALC
Fluoride	ug/L	1000	WQBEL-IR
Iron (total)	ug/L	1000	WQBEL-ALC
Lead (H) (total)	ug/L	0.39	WQBEL-ALC
Lithium (total)	ug/L	2500	WQBEL-IR
Manganese (total)	ug/L	50	WQBEL-HH
Mercury (total)	ug/L	0.012	WQBEL-ALC
Molybdenum (total)	ug/L	10	WQBEL-IR
Nickel (H) (total)	ug/L	12.87	WQBEL-ALC
Nitrate	ug/L	10000	WQBEL-DW
Nitrite	ug/L	1000	WQBEL-DW
Total Nitrate+Nitrite as N	ug/L	10000	WQBEL-DW
Selenium (total)	ug/L	5	WQBEL-ALC
Silver (H) (total)	ug/L	1.1	WQBEL-ALA
Thallium (total)	ug/L	1.7	WQBEL-HH
Vanadium (total)	ug/L	100	WQBEL-HH
Zinc (H) (total)	ug/L	28.95	WQBEL-ALA
TDS	mg/L	500	WQBEL-HH
pH	-	6.5 - 8.5	WQS-GP
TSS	mg/L	20	ELG-MA
DO	mg/L	> = 7.0	WQS-GP
Turbidity (NTU)	NTU	No greater than 5 NTU above natural turbidity	WQS-WS
Alkalinity	ug/L	> = 20,000	WQBEL-ALC
Ammonia as N	mg/L	4.36	WQBEL-ALC
Sulfate	mg/L	250	WQS

M:\1\01\00176\57\A\Report\5 - Closure Water Management Report\Rev 0\Tables\[Table 6.1_Estimated Discharge Criteria.xlsx]Table 6.1_WTP_Limits

ABBREVIATIONS:
WQBEL: Water Quality Based Effluent Limit
ELG: Effluent Limitation Guideline
(H): Hardness dependent criterion
(S): Selenite + Selenate dependent criterion
WQS: Water Quality Standards
HH: Human Health
ALA: Aquatic Life, Acute
ALC: Aquatic Life, Chronic
DW: Drinking Water
MA: Monthly Average
GP: Growth and Propagation of Fish
IR: Irrigation water
WS: Water supply

NOTES:
1. Water quality based effluent limits (WQBELs) are taken from *Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances* dated December 2008.
2. Water quality standards (WQS) are taken from *Alaska Water Quality Standards* (18 AAC 70) dated April 6, 2018.
3. Technology based effluent limits are taken from *Effluent Limitation Guidelines, Subpart J* (40 CFR 440.104) for the Copper, Lead, Zinc, Gold, Silver, and Molybdenum subcategory.
4. Water quality standards for dissolved oxygen, turbidity, and pH are mandatory. Estimated limits are the most stringent of water supply, recreation, or growth and propagation standards. Temperature limits are also required, but dependent on habitat and seasonal considerations.
5. Hardness-dependent criteria (cadmium, copper, chromium III, lead, nickel, silver, zinc) are calculated using the estimated 15th percentile conditions for the receiving streams. The most stringent of the three proposed discharge locations is included in the table.
6. The acute selenium standard is based on the selenite/selenate fraction and was not calculated for this estimate. The chronic standard is used instead.
7. Ammonia: acute criterion is pH dependent; chronic criterion is temperature and pH dependent. Estimate based on pH 7.5 and temperature 14 C. Temperatures below 14C do not change the criterion.
8. The criteria in the table are the applicable regulatory criteria. More stringent discharge criteria may be used by the Pebble Partnership.

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6.2 WQ MODEL INPUTS AND ASSUMPTIONS

The WQ model was developed in GoldSim® using a mass balance approach to represent parameter loading in the flow pathways into and out of each of the facilities. The closure Mine Plan Module water balance was used as the foundation for the WQ model and provided the inflows, outflows, and storage volumes for each facility. The generalized mass balance equation used in the WQM is as follows:

$$C_{New} = \frac{C_A \times Q_A + C_B \times Q_B}{(Q_A + Q_B)}$$

Where C_{New} = mixed concentration (mg/L)
C_A = concentration of stream A (mg/L)
Q_A = flow rate of stream A (m^3/s)
C_B = concentration of stream B (mg/L)
Q_B = flow rate of stream B (m^3/s)

The following inputs and general assumptions apply to the water quality model;

- Complete mixing under steady state conditions (i.e. no reactions or degradation occurs) for all facilities and flow streams.
- For reservoirs for which monthly inflows and outflows were comparable to the volume stored in the reservoir, the water quality of the outflow was assumed to be equal to the water quality of all inflow sources after complete mixing.
- The water balance model was run under a wide variety of climate conditions; 76 different climate realizations were used in the WQ model and the 50th percentile water quality results are presented in this report.
- The WQ model was run on a daily timestep; however, climate inputs were done on a monthly basis and the model assumes consistent values for every day within any month, and results are presented as maximum monthly concentrations.
- The 95th percentile source terms were provided by SRK as parameter concentrations or parameter loadings to be used in the WQ model (SRK 2018). These 95th percentile source term values were used for all simulations. The source terms and source term assumptions used in the WQ model are outlined in Appendix B1, in Table B1.1 and Table B1.2, respectively.
- Baseline water quality data were used to estimate the parameter concentrations in runoff from non-contact surface runoff. Once a facility has been reclaimed, the surface water runoff from the facility is assumed to have the same parameter concentrations as the non-contact surface runoff.
- The tailings beaches of the Bulk TSF are assumed to be capped with material from the Pyritic TSF embankments over the course of five years (Years 10 to 15 of closure), with 20% of the beach capped each year. The capillary break and growth medium are then placed on the beaches, and it is assumed that the water quality from the reclaimed beaches will the same as the background runoff water quality five years after the completion of capping (Year 20 of closure).
- The WQ model does not account for any disturbance of the bulk tailings during the reclamation activities of the Bulk TSF beaches that might affect water quality.
- All of the bulk tailings consolidation seepage is assumed to report to the Bulk TSF supernatant pond, as described in the Mine Plan Module water balance model section of this report.

- Nitrate, Nitrite, and Ammonia concentrations for the source terms were calculated based on the following equations:
  - Nitrate (ion) = 4.43 x Nitrate concentration (mg/L as N)
  - Nitrite = 0.02 x Nitrate (ion) concentration (mg/L), and
  - Ammonia = 0.01 x Nitrite concentration (mg/L).
- Total dissolved solids (TDS) values were calculated as the sum of alkalinity, chloride, fluoride, sulphate, calcium, magnesium, potassium, sodium, and silica.
- Total hardness values were calculated based on the following equation:

$$TH = 2.497 \times Ca + 4.118 \times Mg$$

  Where, TH = total hardness concentration (mg/L as $CaCO_3$)
  Ca = calcium concentration (mg/L)
  Mg = magnesium concentration (mg/L)
- pH values were not modelled.
- The outflow from each water treatment plant is assumed to have the parameter concentrations provided by HDR and listed in Table B1.3 in Appendix B.
- The parameter loads in the sludge and reject from each water treatment plant were added to the Open Pit during closure. These loads were calculated from the concentrations provided by HDR and do not necessarily equal the difference between the inflow and outflow loads to each WTP.

6.3 WQ MODEL RESULTS AND DISCUSSION

The maximum annual (shown as maximum monthly) predicted concentrations within each facility are shown for the different closure phases in Table B2.1 to Table B2.4, in Appendix B2. The highlighted values in these tables indicate where parameter concentrations exceed the discharge water quality criteria, and will therefore require treatment at the water treatment plants. The water quality predictions for the Bulk TSF supernatant pond and the Open Pit Lake are described further below.

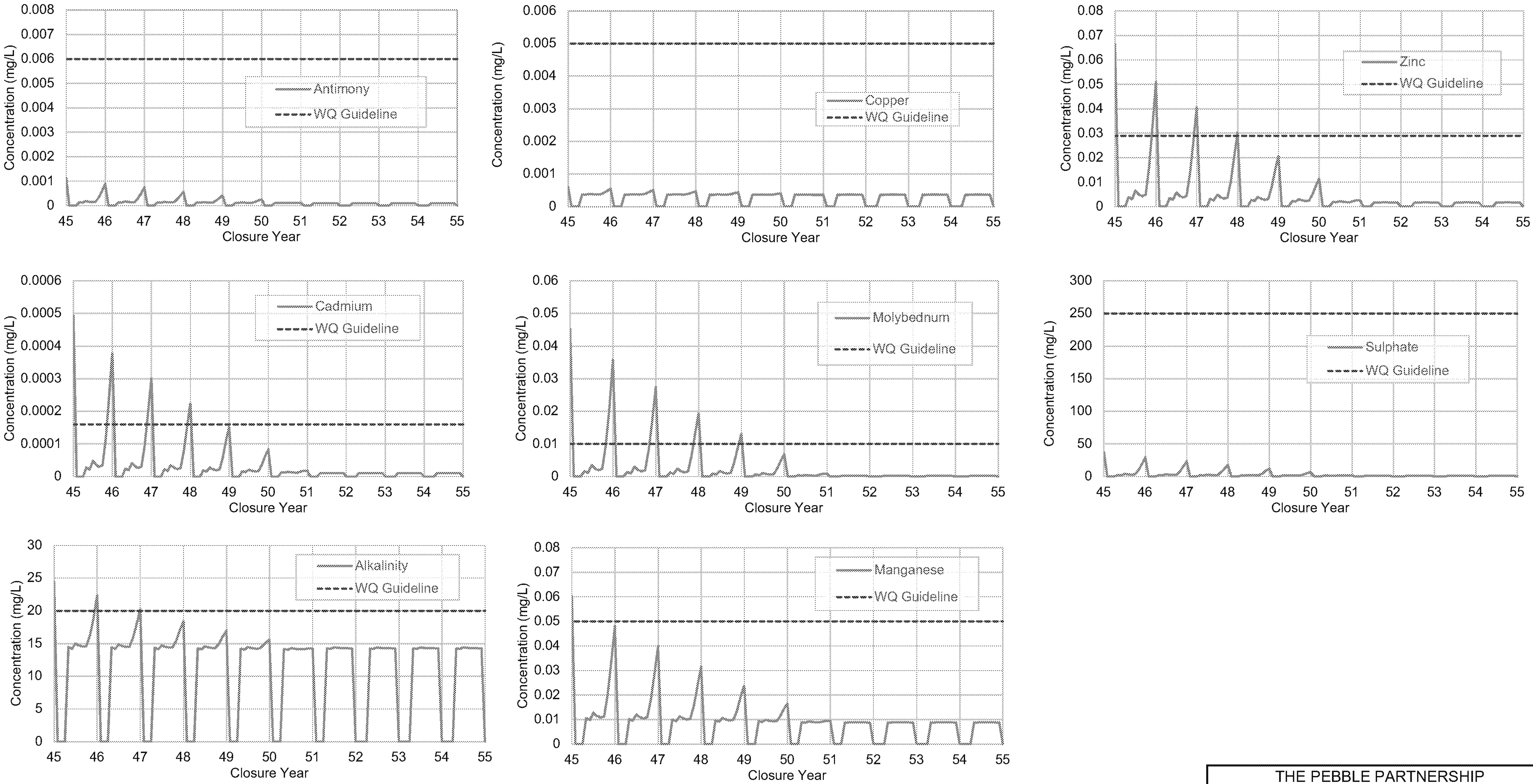
6.3.1 BULK TAILINGS STORAGE FACILITY

During closure, the water quality in the Bulk TSF supernatant pond is expected to vary as follows:

- Prior to closure Phase 1, the cessation of tailings deposition will lead to a general improvement in water quality.
- Tailings beach runoff will continue to affect the bulk TSF supernatant pond quality until the beach is capped using material from the Pyritic TSF embankment (Year 15 of closure).
- Runoff from the cap material will affect the pond water quality during capping (Years 10 to 15) and for five years following capping, until Year 20. After that time, runoff from the reclaimed surface is assumed to be the same as that from the non-contact surface runoff.
- After Year 20, runoff from the reclaimed beach is expected to improve water quality.
- Bulk tailings consolidation is expected to occur at the start of closure and continue until the end of Phase 3 (Year 50 of closure). This consolidation is expected to negatively impact water quality. Since the consolidation of tailings and the corresponding release of pore water is expected to decrease gradually over time, water quality is correspondingly expected to improve.

The water quality of the Bulk TSF supernatant pond is predicted to exceed the discharge criteria until the end of Phase 3/the beginning of Phase 4, when tailings consolidation is expected to finish (Year 50 of closure). The supernatant pond water quality is strongly influenced by the flow of consolidation seepage because of the relatively high concentrations in the consolidation seepage water and the relatively low pond volume. At the end of closure Phase 3, the supernatant pond is influenced mainly by runoff from the reclaimed beaches and precipitation directly on the pond. Water quality at this time, and throughout Phase 4, is predicted to meet the discharge criteria.

The 50th percentile water quality predictions (based on the 95th percentile source terms) for alkalinity, antimony, copper, cadmium, molybdenum, manganese, sulphate and zinc for the Bulk TSF supernatant pond at the end of Phase 3 and the beginning of Phase 4 (Years 45 though 55) are shown on Figure 6.1. These parameters were selected as indicators for water quality because they exceed the discharge water quality criteria during Operations. Starting in Year 50 of closure, the modelled water quality of the Bulk TSF supernatant pond water meets the discharge water quality criteria for all parameters modelled except for alkalinity. The alkalinity water quality criteria is a minimum of 20 mg/L, which is met during operations and closure while the pond water quality is affected by contact water sources. However, during the final phase of closure, the pond water quality is no longer affected by contact water, which is generally high in alkalinity, resulting in low alkalinity concentrations in the supernatant pond that are driven by non-contact runoff from the reclaimed beaches. The water quality of the supernatant pond will be monitored and surplus water from precipitation events will only be discharged from the Bulk TSF to the downstream NFK catchment once it meets discharge water quality criteria.



NOTES:

1. BULK TSF BEACHES UNDERGO CAPPING BEGINNING IN CLOSURE YEAR 10.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
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THE PEBBLE PARTNERSHIP

PEBBLE PROJECT

BULK TSF SUPERNATANT POND 50TH PERCENTILE WATER QUALITY PREDICTIONS FOR THE END OF PHASE 3 AND BEGINNING OF PHASE 4

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P/A NO. VA101-176/57

REF. NO. 5

FIGURE 6.1

REV 0

6.3.2 OPEN PIT LAKE

Water from the Open Pit Lake will be treated at WTP#3. Surplus water from the Open Pit Lake will be pumped to WTP#3 when pumping is required to maintain target water levels while the PAG waste rock and pyritic tailings are being transferred to the Open Pit, and to maintain water levels at or below the MM Level over the long-term.

The water quality model predicts a change in water quality in the Open Pit Lake at Closure Year 15, when the transfer of pyritic tailings and waste rock into the Open Pit Lake is completed. Prior to this change, both the quantity and quality of the inflows to the Open Pit Lake are mainly influenced by the pyritic tailings slurry water and the PAG waste rock. After Closure Year 15, the total inflow to the Open Pit Lake decreases and water quality is dictated by other sources, including surplus water from the Bulk TSF supernatant pond and the Bulk TSF Main SCP, which is pumped to the Open Pit. The concentrations of several parameters in the Open Pit Lake are expected to exceed water quality criteria for the long-term.

7.0 SUMMARY

The key information presented in this report is summarized as follows:

- A description of how mine affected water and stormwater will be managed at the mine site throughout closure of the Project is provided.
- The transfer of PAG waste rock and pyritic tailings from the Pyritic TSF to the Open Pit will take approximately 15 years from the start of closure to complete.
- The closure water balance model indicates the following key results:
  - The water level in the Open Pit can be maintained at a level that allows for the controlled placement of PAG waste rock while maintaining a minimum water cover on the pyritic tailings in the Open Pit.
  - The Open Pit will be allowed to fill with surface water and groundwater following the transfer of PAG waste rock and pyritic tailings, and complete filling is anticipated to take approximately 20 years from the start of closure.
  - Once the Open Pit is full, a maximum dewatering rate of 10 cfs will be required to maintain the water level at or below the Maximum Management Level.
  - The Main WMP will be required to provide storage of surplus water from the Bulk TSF, surplus water from the Bulk TSF Main SCP, and runoff from the Pyritic TSF main embankment, during Phase 1 of closure prior to the water being treated at WTP#2.
  - The maximum capacity of WTP#2 that is required to manage surplus water from the Main WMP during Phase 1 is 41 cfs. WTP#2 will be decommissioned at the end of Phase 1.
  - The maximum capacity of WTP#3 that is required to manage surplus water from the Open Pit during Phase 1 is 20 cfs, and to manage surplus water from the Bulk TSF Main SCP and the Open Pit during Phases 3 and 4 is 49 cfs. The total maximum capacity of WTP#3 is 49 cfs, which is to manage the 38 cfs from the Open Pit and 11 cfs from the Bulk TSF Main SCP.
- Water quality modelling of the Bulk TSF supernatant pond indicates that the water in the pond will exceed the discharge water quality criteria after reclamation of the Bulk TSF facility has occurred, due to the poor water quality of bulk tailings consolidation seepage reporting to the supernatant pond. Therefore, surplus water from the Bulk TSF will be managed at the Open Pit until it has been demonstrated that the water quality of the supernatant pond meets discharge water quality criteria. Under the current modeling assumptions, during closure Year 50 when the bulk tailings consolidation seepage reporting to the supernatant pond is assumed to be minimal, the water quality of the Bulk TSF supernatant pond will meet all discharge criteria except for alkalinity.
- The water quality modelling results for the Bulk TSF seepage indicate that under the current assumptions the seepage from the Bulk TSF will require treatment at WTP#3 for the long-term.

8.0 REFERENCES

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9.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

Prepared: EKennedy
Erica Kennedy, M.Eng., E.I.T.
Junior Engineer

Prepared: Alana Shewan
Alana Shewan, MASc., P.Eng.
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REGISTERED PROFESSIONAL ENGINEER

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Jaime Cathcart, Ph.D., P.E. (Alaska)
Specialist Hydrotechnical Engineer
Associate

Approval that this document adheres to Knight Piésold Quality Systems:

APPENDIX A

Water Balance Flow Schematics and Average Annual Flow Balances

(Pages A-1 to A-10)

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TABLE A.1

THE PEBBLE LIMITED PARTNERSHIP
PEBBLE PROJECT

FLOW PATH NUMBER AND DESCRIPTIONS

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Flow Path Number and Description		Flow Path Number and Description (Cont.)	
1	Direct Precipitation on Open Pit	41	Diversion Channel Leakage to Bulk TSF Main SCP
2	Undisturbed Surface Runoff to Open Pit	42	Bulk TSF Main Embankment Runoff
3	Diversion Channel Leakage to Open Pit	43	Pond Evaporation from Bulk TSF Main SCP
4	Groundwater to Open Pit	44	Surplus Water from Bulk TSF Main SCP
5	Additional Snow blow to Open Pit	45	Undisturbed Surface Runoff to Bulk TSF South Embankment SCP
6	Open Pit Dewatering	46	Diversion Channel Leakage to Bulk TSF South Embankment SCP
7	Direct Precipitation on OP WMP	47	Bulk TSF South Embankment Runoff
8	Undisturbed Surface Runoff to OP WMP	48	Direct Precipitation on Main WMP
9	Pond Evaporation from OP WMP	49	Undisturbed Surface Runoff to Main WMP
10	Dust Suppression	50	Diversion Channel Leakage to Main WMP
11	Surplus to Main WMP from OP WMP	51	Mill Site Runoff
12	Surplus to WTP#1 from OP WMP	52	Pyritic TSF Main Embankment Runoff
13	Water in Ore	53	Pond Evaporation from Main WMP
14	Treated Water from Mill/Process	54	Main WMP Water to WTP#2
15	Reclaim Water from Main WMP for Mill/Process	55	Reject Flows from WTP #1
16	Water in Concentrate	56	Flows Released to Environment from WTP #1
17	Bulk Tailings Slurry Water	57	Reject Flows from WTP #2
18	Pyritic Tailings Slurry Water	58	Flows Released to Environment from WTP #2
19	Treated Water for Cooling Towers	59	Diverted Runoff from Quarry B
20	Cooling Tower Evaporation	60	Diverted Runoff from Quarry C
21	Blowdown Water to Main WMP	61	Diversion Channel Flow
22	Direct Precipitation on Pyritic TSF	62	Reject Flows from WTP #3
23	Undisturbed Surface Runoff to Pyritic TSF	63	Flows Released to Environment from WTP #3
24	Diversion Channel Leakage to Pyritic TSF	64	Pyritic Tailings Re-Slurry Make-up Water from Open Pit
25	Recycle from Seepage Collection Ponds to Pyritic TSF	65	Pyritic Tailings Re-Slurry Water to Open Pit
26	Pond Evaporation from Pyritic TSF	66	Pyritic Tailings Re-Slurry Make-up Water from Main WMP
27	Pyritic Tailings Void Losses in the Pyritic TSF	67	Pyritic Tailings Void Losses in the Open Pit
28	PAG Waste Rock Void Losses in the Pyritic TSF	68	PAG Waste Rock Void Losses in the Open Pit
29	Surplus Water from Pyritic TSF	69	Reclaimed Bulk Tailings Beach Runoff
30	Direct Precipitation on Supernatant Pond	70	Pond Evaporation from Open Pit
31	Undisturbed Surface Runoff to Bulk TSF	71	Surplus to WTP#3 from OP WMP during drainage
32	Diversion Channel Leakage to Bulk TSF	72	Pit Wall Runoff from Open Pit
33	Recycle from Seepage Collection Ponds to Bulk TSF	73	Sludge Flows from WTP#2
34	Bulk Tailings Beach Runoff	74	Sludge Flows from WTP#3
35	Pond Evaporation from Supernatant Pond	75	Seepage through South and East Embankments
36	Bulk Tailings Void Losses	76	Recycle from Seepage Collection Ponds to Bulk TSF Main SCP
37	Seepage through Main Embankment	77	Tailings Consolidation Seepage
38	Surplus Water from Bulk TSF		
39	Direct Precipitation on Bulk TSF Main SCP		
40	Undisturbed Surface Runoff to Bulk TSF Main SCP		

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NOTES:

1. FLOW PATH NUMBER CORRESPONDS TO FLOW SCHEMATIC PRESENTED ON FIGURES A.1 TO A.4.

2. OP = OPEN PIT, PAG = POTENTIALLY ACID GENERATING, SCP = SEDIMENT COLLECTION POND, TSF = TAILING STORAGE FACILITY, WMP = WATER MANAGEMENT POND, WTP = WATER TREATMENT PLANT.

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TABLE A.2

PEBBLE LIMITED PARTNERSHIP
PEBBLE PROJECT

AVERAGE ANNUAL FLOW BALANCE
CLOSURE PHASE 1 - YEAR 10

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Flow Path Number and Description		Average Annual Flow (cfs)		
		Relatively Dry Conditions	**Average Conditions**	**Relatively Wet Conditions**
Open Pit				
Open Pit Inflows				
1	Direct Precipitation	1	1	2
2	Undisturbed Surface Runoff	<1	1	1
3	Diversion Channel Leakage	<1	<1	1
4	Groundwater	5	5	5
5	Additional Snowblow	1	1	1
65	Pyritic Tailings Re-Slurry Water to Open Pit	36	36	36
72	Pit Wall Runoff	2	3	3
57 + 73	Reject Flows and Sludge Flows from WTP #2	1	1	1
62 + 74	Reject Flows and Sludge Flows from WTP #3	0	0	0
	Subtotal Inflows	**46**	**47**	**50**
Open Pit Outflows				
6	Open Pit Dewatering to WTP#3	<1	<1	<1
64	Make-up Water to Pyritic TSF	28	26	24
67	Pyritic Tailings Void Losses	3	3	3
68	PAG Waste Rock Void Losses	2	2	2
70	Pond Evaporation	<1	<1	<1
	Subtotal Outflows	**33**	**31**	**29**
	Change in Storage	**13**	**16**	**21**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Pyritic Tailings and PAG Waste Rock Management Facility (Pyritic TSF)				
Pyritic TSF Inflows				
22	Direct Precipitation	2	3	3
23	Undisturbed Surface Runoff	2	4	5
24	Diversion Channel Leakage	<1	<1	<1
25	Seepage Collection Recycle Ponds	<1	<1	<1
64	Make-up Water from Open Pit	28	26	24
66	Make-up Water from Main WMP	0	0	0
	Subtotal Inflows	**32**	**32**	**32**
Pyritic TSF Outflows				
26	Pond Evaporation	1	1	<1
29	Surplus Water from Pyritic TSF	0	0	0
65	Pyritic Tailings Re-Slurry Water to Open Pit	36	36	36
	Subtotal Outflows	**36**	**37**	**36**
	Change in Storage	**-4**	**-4**	**-4**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk Tailings Management Facility (Bulk TSF)				
Bulk TSF Inflows				
30	Direct Precipitation on Supernatant Pond	1	2	3
31	Undisturbed Surface Runoff	5	8	10
32	Diversion Channel Leakage	<1	<1	<1
34	Bulk Tailings Beach Runoff - Reclaimation in Progress	9	14	18
77	Bulk Tailings Consolidation Seeapge	2	2	2
	Subtotal Inflows	**17**	**26**	**34**
Bulk TSF Outflows				
35	Pond Evaporation	<1	<1	<1
37 + 75	Seepage through Emankments	5	6	6
38	Surplus water from Bulk TSF to Main WMP	17	25	33
	Subtotal Outflows	**23**	**31**	**40**
	Change in Storage	**-5**	**-4**	**-6**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk TSF Main Embankment Seepage Collection Pond (Bulk TSF Main SCP)				
Bulk TSF Main SCP Inflows				
39	Direct Precipitation	<1	1	1
40	Undisturbed Surface Runoff	2	4	5
41	Diversion Channel Leakage	<1	1	1
42	Bulk TSF Main Embankment Runoff	1	2	2
37	Seepage through Emankments	5	6	6
76	Surplus from South and East SCRP	2	3	3
	Subtotal Inflows	**10**	**17**	**17**
Bulk TSF Main SCP Outflows				
43	Pond Evaporation	<1	<1	<1
44	Surplus Water to Main WMP	9	13	14
	Subtotal Outflows	**9**	**13**	**14**
	Change in Storage	**1**	**4**	**4**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**

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TABLE A.2 (continued)

PEBBLE LIMITED PARTNERSHIP
PEBBLE PROJECT

AVERAGE ANNUAL FLOW BALANCE
CLOSURE PHASE 1 - YEAR 10

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Flow Path Number and Description		Average Annual Flow (cfs)		
		Relatively Dry Conditions	Average Conditions	Relatively Wet Conditions
Bulk TSF South and East Seepage and Recycle Collection Pond				
Seepage Pond Inflows				
45	Undisturbed Surface Runoff	1	2	2
46	Diversion Channel Leakage	<1	0	1
47	Bulk TSF South Embankment Runoff	<1	<1	<1
75	Bulk TSF Seepage	<1	<1	<1
	Subtotal Inflows	**2**	**3**	**3**
Seepage Pond Outflows				
76	Surplus Water to Bulk TSF Main SCP	2	3	3
	Subtotal Outflows	**2**	**3**	**3**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Main Water Management Pond (Main WMP)				
Main WMP Inflows				
29	Surplus Water from Pyritic TSF	0	0	0
38	Surplus from Bulk TSF	17	25	33
44	Surplus Water from Bulk TSF Main SCP	9	13	14
48	Direct Precipitation	3	4	6
49	Undisturbed Surface Runoff	5	8	11
50	Diversion Channel Leakage	<1	<1	<1
52	Pyritic TSF Main Embankment Runoff	1	1	1
	Subtotal Inflows	**35**	**52**	**66**
Main WMP Outflows				
53	Pond Evaporation	1	1	1
54	Surplus Water to WTP#2	41	41	41
66	Make-up Water to Pyritic TSF	0	0	0
	Subtotal Outflows	**42**	**42**	**43**
	Change in Storage	**-7**	**10**	**23**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Water Treatment Plant #2 (WTP #2)				
WTP#2 Inflows				
54	Surplus from Main WMP	41	41	41
	Subtotal Inflows	**41**	**41**	**41**
WTP#2 Outflows				
57 + 73	Reject Flows and Sludge Flows from WTP #2	1	1	1
58	Flows Released to Environment	40	40	40
	Subtotal Outflows	**41**	**41**	**41**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Water Treatment Plant #3 (WTP #3)				
WTP#3 Inflows				
6	Open Pit Dewatering	0	0	0
	Subtotal Inflows	**0**	**0**	**0**
WTP#3 Outflows				
62 + 74	Reject Flows and Sludge Flows from WTP #3	0	0	0
63	Flows Released to Environment	0	0	0
	Subtotal Outflows	**0**	**0**	**0**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Flows Released from WTPs to Downstream Environment				
58	Treated Flows from WTP#2	40	40	40
63	Treated Flows from WTP#3	0	0	0
	Total Flows Released to Downstream Environment	**40**	**40**	**40**

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NOTES:

1. FLOW PATH NUMBER CORRESPONDS TO FLOW SCHEMATIC PRESENTED ON FIGURE A.1.
2. CHANGE IN STORAGE WITHIN THE PONDS ARE A FUNCTION OF THE WATER MANAGEMENT OPERATING CRITERIA. A CHANGE IN STORAGE INDICATES IF THE POND HAS ACCUMULATED OR DECREASED POND VOLUME FROM THE START OF THE YEAR.

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TABLE A.3

PEBBLE LIMITED PARTNERSHIP
PEBBLE PROJECT

AVERAGE ANNUAL FLOW BALANCE
CLOSURE PHASE 2 - YEAR 20

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Flow Path Number and Description		Average Annual Flow (cfs)		
		Relatively Dry Conditions	Average Conditions	Relatively Wet Conditions
Open Pit				
Open Pit Inflows				
1	Direct Precipitation	3	3	4
2	Undisturbed Surface Runoff	2	2	3
4	Groundwater	4	4	4
5	Additional Snowblow	1	1	1
38	Surplus from Bulk TSF	17	17	17
44	Surplus from Bulk TSF Main SCP	9	12	16
62 + 74	Reject Flows and Sludge Flows from WTP #3	0	0	0
72	Pit Wall Runoff from Open Pit	1	1	1
	Subtotal Inflows	**36**	**41**	**47**
Open Pit Outflows				
6	Open Pit Dewatering	0	0	0
70	Pond Evaporation	1	1	1
	Subtotal Outflows	**1**	**1**	**1**
	Change in Storage	**35**	**40**	**46**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk Tailings Management Facility (Bulk TSF)				
Bulk TSF Inflows				
30	Direct Precipitation on Supernatant Pond	1	1	3
31	Undisturbed Surface Runoff	5	6	10
69	Bulk Tailings Reclaimed Beach Runoff	9	12	19
77	Bulk Tailings Consolidation Seeapge	1	1	1
	Subtotal Inflows	**16**	**21**	**33**
Bulk TSF Outflows				
35	Pond Evaporation	<1	<1	<1
37	Seepage through Embankments	4	4	4
38	Surplus to Open Pit	17	17	17
	Subtotal Outflows	**20**	**21**	**21**
	Change in Storage	**-4**	**0**	**12**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk TSF Main Embankment Seepage Collection Pond (Bulk TSF Main SCP)				
Seepage Pond Inflows				
39	Direct Precipitation	<1	1	1
40	Undisturbed Surface Runoff	2	3	5
41	Diversion Channel Leakage	<1	1	1
42	Bulk TSF Main Embankment Runoff	1	1	2
37	Seepage through Embankments	4	4	4
76	Recycle from Seepage Collection Ponds to Bulk TSF Main SCP	2	2	3
	Subtotal Inflows	**9**	**12**	**16**
Seepage Pond Outflows				
43	Pond Evaporation	<1	<1	<1
44	Surplus Water to Open Pit	9	12	16
	Subtotal Outflows	**9**	**12**	**16**
	Change in Storage	**0**	**0**	**0**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk TSF South and East Seepage and Recycle Collection Pond				
Seepage Pond Inflows				
45	Undisturbed Surface Runoff	1	2	2
46	Diversion Channel Leakage	<1	<1	1
47	Bulk TSF South Embankment Runoff	<1	<1	<1
75	Bulk TSF Seepage	<1	<1	<1
	Subtotal Inflows	**2**	**2**	**3**
Seepage Pond Outflows				
76	Surplus Water to Bulk TSF Main SCP	2	2	3
	Subtotal Outflows	**2**	**2**	**3**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Water Treatment Plant #3 (WTP #3)				
WTP#3 Inflows				
6	Open Pit Dewatering	0	0	0
	Subtotal Inflows	**0**	**0**	**0**
WTP#3 Outflows				
62 + 74	Reject Flows and Sludge Flows from WTP #3	0	0	0
63	Flows Released to Environment	0	0	0
	Subtotal Outflows	**0**	**0**	**0**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Flows Released to Downstream Environment				
63	Treated Flows from WTP#3	0	0	0
	Total Flows Released to Downstream Environment	**0**	**0**	**0**

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NOTES:

1. FLOW PATH NUMBER CORRESPONDS TO FLOW SCHEMATIC PRESENTED ON FIGURE A.2.
2. CHANGE IN STORAGE WITHIN THE PONDS ARE A FUNCTION OF THE WATER MANAGEMENT OPERATING CRITERIA. A CHANGE IN STORAGE INDICATES IF THE POND HAS ACCUMULATED OR DECREASED POND VOLUME FROM THE START OF THE YEAR.

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REV	DATE	DESCRIPTION	PREP'D	RVW'D

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TABLE A.4

PEBBLE LIMITED PARTNERSHIP
PEBBLE PROJECT

AVERAGE ANNUAL FLOW BALANCE
CLOSURE PHASE 3 - YEAR 40

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Flow Path Number and Description		Average Annual Flow (cfs)		
		Relatively Dry Conditions	Average Conditions	Relatively Wet Conditions
Open Pit				
Open Pit Inflows				
1	Direct Precipitation	2	3	4
2	Undisturbed Surface Runoff	1	3	3
4	Groundwater	4	4	4
5	Additional Snowblow	1	1	1
38	Surplus Water from Bulk TSF	0	25	42
62 + 74	Reject Flows and Sludge Flows from WTP #3	1	1	1
72	Pit Wall Runoff from Open Pit	<1	1	1
	Subtotal Inflows	**10**	**37**	**56**
Open Pit Outflows				
6	Surplus to WTP#3	19	29	30
70	Pond Evaporation	1	1	1
	Subtotal Outflows	**20**	**29**	**31**
	Change in Storage	**-9**	**8**	**26**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk Tailings Management Facility (Bulk TSF)				
Bulk TSF Inflows				
30	Direct Precipitation on Supernatant Pond	1	1	2
31	Undisturbed Surface Runoff	4	7	10
69	Reclaimed Bulk Tailings Beach Runoff	9	15	19
77	Bulk Tailings Consolidation Seeapge	<1	<1	<1
	Subtotal Inflows	**13**	**24**	**31**
Bulk TSF Outflows				
35	Pond Evaporation	<1	<1	<1
37 + 75	Seepage through the Embankments	2	2	2
38	Surplus to Open Pit	0	25	42
	Subtotal Outflows	**2**	**27**	**44**
	Change in Storage	**12**	**-3**	**-13**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk TSF Main Embankment Seepage Collection Pond (Bulk TSF Main SCP)				
Seepage Pond Inflows				
39	Direct Precipitation	<1	1	1
40	Undisturbed Surface Runoff	2	4	5
41	Diversion Channel Leakage	<1	1	1
42	Bulk TSF Main Embankment Runoff	1	2	2
37	Seepage through the Embankments	2	2	2
76	Recycle from Seepage Collection Ponds to Bulk TSF Main SCP	1	2	3
	Subtotal Inflows	**6**	**10**	**13**
Seepage Pond Outflows				
43	Pond Evaporation	<1	<1	<1
44	Surplus Water to WTP#3	<1	<1	<1
	Subtotal Outflows	**0**	**0**	**0**
	Change in Storage	**6**	**10**	**13**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk TSF South and East Seepage and Recycle Collection Pond				
Seepage Pond Inflows				
45	Undisturbed Surface Runoff	1	2	2
46	Diversion Channel Leakage	<1	<1	1
47	Bulk TSF South Embankment Runoff	<1	<1	<1
75	Bulk TSF Seepage	<1	<1	<1
	Subtotal Inflows	**1**	**2**	**3**
Seepage Pond Outflows				
76	Surplus Water to Bulk TSF Main SCP	1	2	3
	Subtotal Outflows	**1**	**2**	**3**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Water Treatment Plant #3 (WTP #3)				
WTP#3 Inflows				
6	Open Pit Dewatering	19	29	30
44	Surplus from Bulk TSF Main SCP	<1	<1	<1
	Subtotal Inflows	**19**	**29**	**30**
WTP#3 Outflows				
62 + 74	Reject Flows and Sludge Flows from WTP #3	1	1	1
63	Flows Released to Environment	18	28	29
	Subtotal Outflows	**19**	**29**	**30**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Flows Released to Downstream Environment				
63	Treated Flows from WTP#3	18	28	29
	Total Flows Released to Downstream Environment	**18**	**28**	**29**

M:\1\01\00176\57\A\Data\Water Management Plan\Closure\[Water Balance Schematic Results_WBM029_rev0_byRealization.xlsx]Table_WaterBalanceResults_3

NOTES:
1. FLOW PATH NUMBER CORRESPONDS TO FLOW SCHEMATIC PRESENTED ON FIGURE A.3.
2. CHANGE IN STORAGE WITHIN THE PONDS ARE A FUNCTION OF THE WATER MANAGEMENT OPERATING CRITERIA. A CHANGE IN STORAGE INDICATES IF THE POND HAS ACCUMULATED OR DECREASED POND VOLUME FROM THE START OF THE YEAR.

0	21Sept'18	ISSUED WITH REPORT	AS	JGC
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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TABLE A.5

PEBBLE LIMITED PARTNERSHIP
PEBBLE PROJECT

AVERAGE ANNUAL FLOW BALANCE
CLOSURE PHASE 4 - YEAR 50

Print Sep/21/18 15:40:41

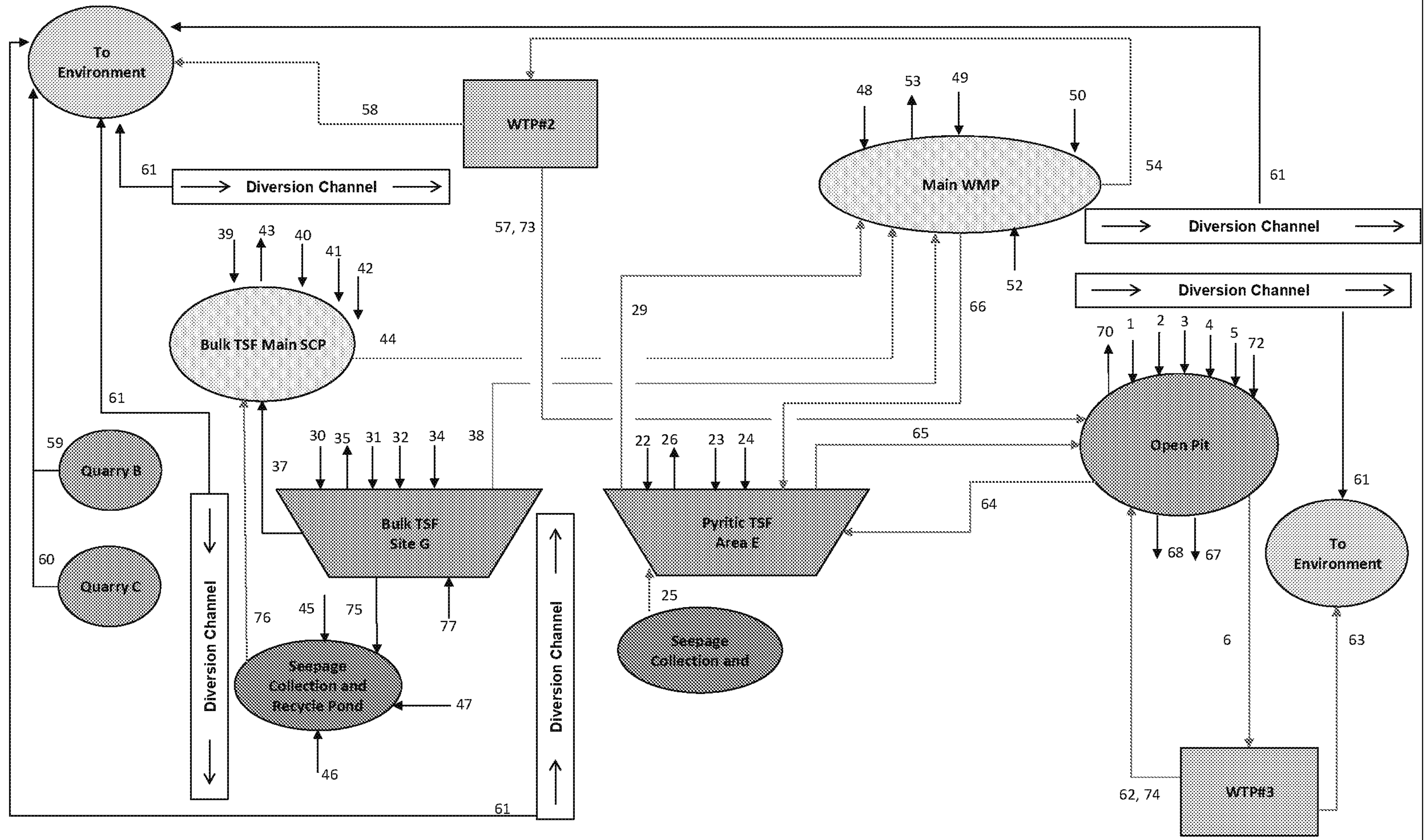
Flow Path Number and Description		Average Annual Flow (cfs)		
		Relatively Dry Conditions	Average Conditions	Relatively Wet Conditions
Open Pit				
Open Pit Inflows				
1	Direct Precipitation	2	3	5
2	Undisturbed Surface Runoff	1	2	3
4	Groundwater	4	4	4
5	Additional Snowblow	1	1	1
62 + 74	Reject Flows and Sludge Flows from WTP #3	<1	<1	<1
72	Pit Wall Runoff from Open Pit	<1	1	1
	Subtotal Inflows	**7**	**10**	**14**
Open Pit Outflows				
6	Open Pit Dewatering	2	6	6
70	Pond Evaporation	1	1	1
	Subtotal Outflows	**3**	**6**	**7**
	Change in Storage	**4**	**4**	**7**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk Tailings Management Facility (Bulk TSF)				
Bulk TSF Inflows				
30	Direct Precipitation on Supernatant Pond	<1	1	2
31	Undisturbed Surface Runoff	3	7	12
69	Reclaimed Bulk Tailings Beach Runoff	5	13	19
77	Bulk Tailings Consolidation Seeapge	0	0	0
	Subtotal Inflows	**7**	**21**	**33**
Bulk TSF Outflows				
35	Pond Evaporation	<1	<1	<1
37	Seepage through Main Embankment	1	1	1
38	Surplus to Environment	7	20	32
75	Seepage through South and East Embankments	<1	<1	<1
	Subtotal Outflows	**7**	**21**	**33**
	Change in Storage	**0**	**0**	**0**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk TSF Main Embankment Seepage Collection Pond (Bulk TSF Main SCP)				
Seepage Pond Inflows				
39	Direct Precipitation	<1	1	1
40	Undisturbed Surface Runoff	1	3	5
41	Diversion Channel Leakage	<1	1	1
42	Bulk TSF Main Embankment Runoff	1	1	2
37	Seepage through Main Embankment	1	1	1
76	Recycle from Seepage Collection Ponds to Bulk TSF Main SCP	1	1	3
	Subtotal Inflows	**4**	**9**	**13**
Seepage Pond Outflows				
43	Pond Evaporation	<1	<1	<1
44	Surplus Water to WTP#3	3	5	8
	Subtotal Outflows	**3**	**5**	**9**
	Change in Storage	**1**	**4**	**4**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk TSF South and East Seepage and Recycle Collection Pond				
Seepage Pond Inflows				
45	Undisturbed Surface Runoff	1	1	2
46	Diversion Channel Leakage	<1	<1	1
47	Bulk TSF South Embankment Runoff	<1	<1	<1
75	Bulk TSF Seepage	<1	<1	<1
	Subtotal Inflows	**1**	**1**	**3**
Seepage Pond Outflows				
76	Surplus Water to Bulk TSF Main SCP	1	1	3
	Subtotal Outflows	**1**	**1**	**3**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Water Treatment Plant #3 (WTP #3)				
WTP#3 Inflows				
6	Open Pit Dewatering	2	6	6
44	Surplus Water from Bulk TSF Main SCP	3	5	8
	Subtotal Inflows	**5**	**10**	**14**
WTP#3 Outflows				
62 + 74	Reject Flows and Sludge Flows from WTP #3	<1	<1	<1
63	Flows Released to Environment	5	10	14
	Subtotal Outflows	**5**	**10**	**14**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Flows Released to Downstream Environment				
63	Treated Flows from WTP#3	5	10	14
	Total Flows Released to Downstream Environment	**5**	**10**	**14**

M:\1\01\00176\57\A\Data\Water Management Plan\Closure\[Water Balance Schematic Results_WBM029_rev0_byRealization.xlsx]Table_WaterBalanceResults_4

NOTES:

1. FLOW PATH NUMBER CORRESPONDS TO FLOW SCHEMATIC PRESENTED ON FIGURE A.4.
2. CHANGE IN STORAGE WITHIN THE PONDS ARE A FUNCTION OF THE WATER MANAGEMENT OPERATING CRITERIA. A CHANGE IN STORAGE INDICATES IF THE POND HAS ACCUMULATED OR DECREASED POND VOLUME FROM THE START OF THE YEAR.

0	21Sept'18	ISSUED WITH REPORT	AS	JGC
REV	DATE	DESCRIPTION	PREP'D	RVW'D



LEGEND:

3 FLOW PATH NUMBER

RUNOFF, GROUNDWATER, AND SEEPAGE PATHWAY

PUMPED FLOW

NOTES:

1. FLOW PATH NUMBERS CORRESPOND WITH FLOW VALUES SUMMARIZED IN TABLE A.2.
2. BULK TSF BEACHES UNDERGO CAPPING BEGINNING IN CLOSURE YEAR 10.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	21SEPT'18	ISSUED WITH REPORT	ELK	AS

THE PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

WATER BALANCE FLOW SCHEMATIC
CLOSURE - PHASE 1

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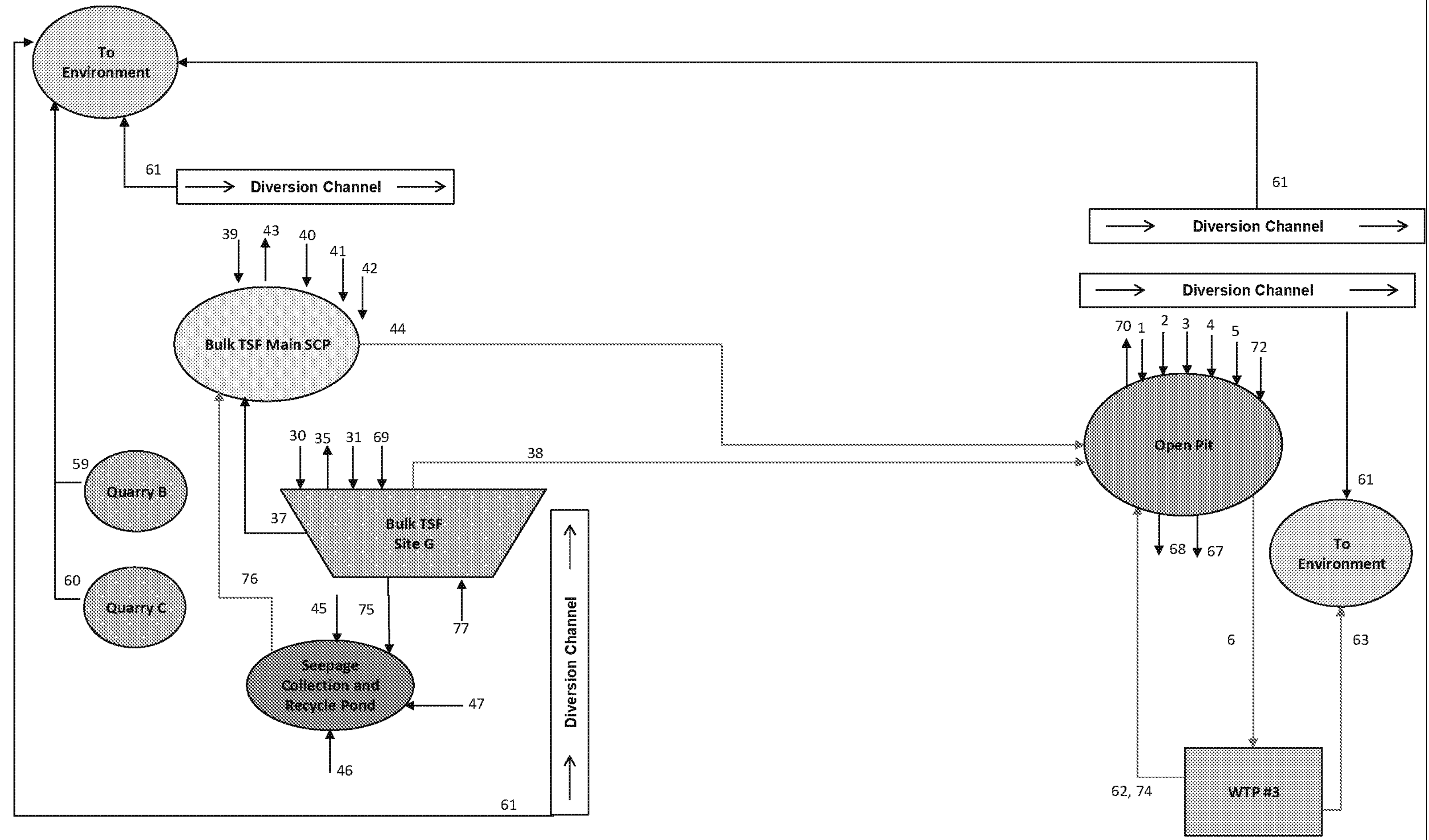
P/A NO. VA101-176/57 | REF. NO. 5

FIGURE A.1 | REV 0



LEGEND:

3 FLOW PATH NUMBER

RUNOFF, GROUNDWATER, AND SEEPAGE PATHWAY

PUMPED FLOW

NOTES:

1. FLOW PATH NUMBERS CORRESPOND WITH FLOW VALUES SUMMARIZED IN TABLE A.3.
2. WTP#3 REPLACES WTP#1 FOR CLOSURE PHASES.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	21SEPT'18	ISSUED WITH REPORT	ELK	AS

THE PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

WATER BALANCE FLOW SCHEMATIC CLOSURE - PHASE 2

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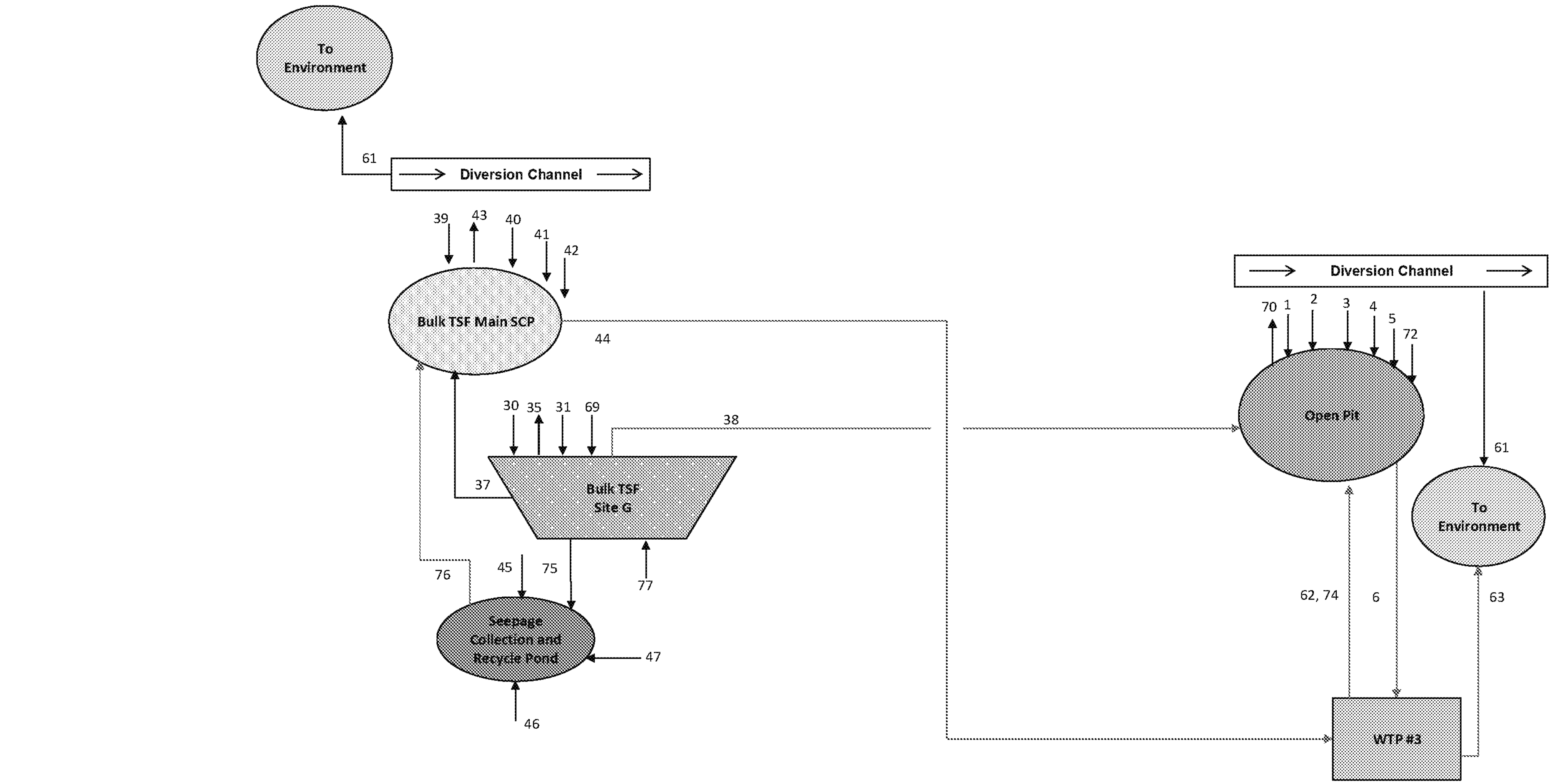
P/A NO. VA101-176/57 REF. NO. 5

FIGURE A.2 REV 0



LEGEND:

3 FLOW PATH NUMBER

RUNOFF, GROUNDWATER, AND SEEPAGE PATHWAY

PUMPED FLOW

NOTES:

1. FLOW PATH NUMBERS CORRESPOND WITH FLOW VALUES SUMMARIZED IN TABLE A.4.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	21SEPT'18	ISSUED WITH REPORT	ELK	AS

THE PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

WATER BALANCE FLOW SCHEMATIC
CLOSURE - PHASE 3

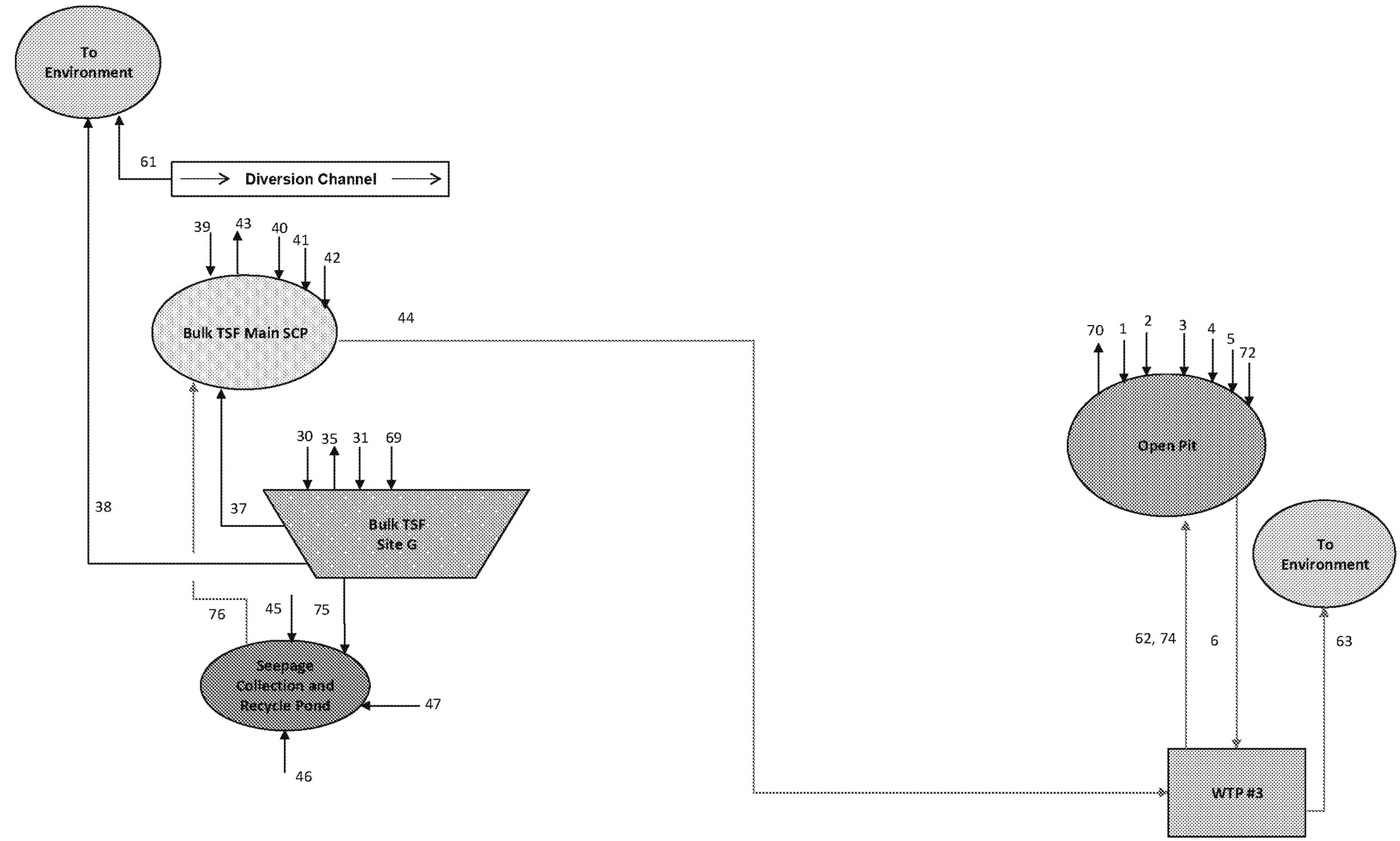
Knight Piésold CONSULTING

P/A NO. VA101-176/57

REF. NO. 5

FIGURE A.3

REV 0



LEGEND:

3 FLOW PATH NUMBER

RUNOFF, GROUNDWATER, AND SEEPAGE PATHWAY

PUMPED FLOW

NOTES:

1. FLOW PATH NUMBERS CORRESPOND WITH FLOW VALUES SUMMARIZED IN TABLE A.5.

0	21SEPt18	ISSUED WITH REPORT	ELK	AS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

THE PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

WATER BALANCE FLOW SCHEMATIC CLOSURE -PHASE 4

Knight Piésold CONSULTING

P/A NO. VA101-176/57 REF. NO. 5

FIGURE A.4 REV 0

APPENDIX B

Water Quality Model Inputs and Results

Appendix B1
Water Quality Model Source Terms and Assumptions

Appendix B2
Water Quality Model Results

Appendix B1

Water Quality Source Terms and Assumptions

(Tables B1.1 to B1.3)

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TABLE B1.1

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

CLOSURE WATER QUALITY SOURCE TERMS AND ASSUMPTIONS
95TH PERCENTILE GEOCHEMICAL SOURCE TERMS

Print: Sep/21/18 15:04:07

Parameters	Background				Overburden	Other Rock				Open Pit					Tailings						Area E	Area E - Decommissioning	Open Pit - Closure
	Direct Precipitation	Non-Contact Surface Water	Non-Contact Surface Water	Ground Water	Stockpiles	Waste Rock	Waste Rock	Quarried Rock Fill (Dams)	Quarried Rock Fill (Dams)	Wall Runoff	Wall Runoff	Wall Runoff	In-Pit Stockpile	In-Pit Stockpile	Bulk Tailings Water	Fresh Ore Leaching + reagent	Rougher tailings	Ore	Tailings Pond Adjustment	Rougher Tailings Sand Wedge	PAG WR is 17% of facility area	Exposed Waste Rock	Backfilled Waste Rock
		NFK (NK119A)	SFK SK100F	Pit area		Tertiary	Tertiary	Non-Acidic	Non-Acidic	Pre-Tertiary - Non-Acidic	Pre-Tertiary - Acidic	Tertiary - Non-Acidic	Non-Acidic	Non-Acidic	Supernatant		Runoff	Entrained moisture	Pond	Seepage	Total Load	High Pyritic Taillings	High Pyritic taillings
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/t of new rock	mg/L	mg/t of new rock	mg/L	mg/L	mg/L	mg/L	mg/t of new rock	mg/L	mg/t of ore	mg/m2/week	mg/L	mg/L	mg/L	kg/year	mg/L	mg/L
pH	5.5	6.5	6.8	6.7	6.8	7.7	-	8.4	-	8.1	3.5	8.2	8	-	8	-	0.0	6.7	8	8.6	-	3.0	3.0
Alkalinity	0	15	18	33	18	26	-	490	-	49	0	69	800	-	97	220000	220	33	-	770	23000	14.0	14.0
Chloride	0	0.62	0.71	0.8	0.71	23	-	8.3	-	2.2	6.935	2.260	23.000	-	17.000	2068.840	1.684	0.804	-	9.300	6042.718	6.935	6.935
Fluoride	0	0.032	0.04	0.072	0.04	0.86	-	0.87	-	0.32	0.45	0.11	1.8	-	0.48	0	0.55	0.072	-	0.9	1900	2.785	2.785
Sulfate	0	1.2	7.8	4.9	7.8	1500	-	2400	-	88	280	29	2400	-	160	920000	67	4.9	2400	2400	800000	31000	31000
Aluminum	0	0.036	0.054	0.0034	0.054	0.049	-	1.3	-	0.0011	23	0.0015	2.6	-	0.011	480	0.38	0.0034	0.0006	2.5	980	750	750
Antimony	0	0.00011	0.000064	0.000031	0.000064	0.2	-	0.15	-	0.0022	0.001	0.018	0.2	-	0.0025	2.4	0.021	0.000031	-	0.2	76	0.036	0.036
Arsenic	0	0.00015	0.00038	0.00045	0.00038	0.19	-	0.19	-	0.02	0.034	0.043	0.4	-	0.002	3.3	0.096	0.00045	-	0.26	67	0.90	0.90
Barium	0	0.0025	0.0049	0.0064	0.0049	6.2	-	0.1	-	0.14	0.06	1	0.36	-	0.023	42	0.043	0.0064	-	0.15	370	0.07	0.07
Cadmium	0	0.000011	0.000013	0.00002	0.000013	0.011	-	0.0055	-	0.002	0.026	0.00023	0.22	-	0.000061	14	0.00017	<0.00002	-	0.01	7.2	1.1	1.1
Calcium	0	3.9	6.1	14	6.1	540	-	760	-	30	9.9	25	940	-	66	150000	72	14	-	770	290000	800	800
Chromium	0	0.00022	0.00027	0.00051	0.00027	0.02	-	0.02	-	0.00082	0.0017	0.0011	0.02	-	<0.0005	3.1	0.0016	0.00051	-	0.02	6.1	0.19	0.19
Cobalt	0	0.000076	0.00011	0.0001	0.00011	0.022	-	0.049	-	0.02	0.25	0.00061	0.88	-	0.00064	31	0.00033	0.0001	-	0.05	55	3.2	3.2
Copper	0	0.00037	0.0021	0.00044	0.0021	0.025	-	0.16	-	0.0064	6.4	0.0041	1.3	-	0.01	30000	0.017	0.00044	0.01	0.37	1400	640	640
Iron	0	0.15	0.55	0.02	0.55	0.0021	-	1.7	-	0.002	39	0.002	16	-	<0.03	11000	0.1	0.02	0.002	1.8	370	1800	1800
Lead	0	0.00016	0.00028	0.0001	0.00028	0.012	-	0.05	-	0.000091	0.0081	0.00047	0.062	-	<0.00005	21	0.00021	0.0001	-	0.05	3.4	0.049	0.049
Magnesium	0	0.73	1.5	1.1	1.5	49	-	99	-	10	1.9	2.5	120	-	16	85000	18	1.1	-	99	92000	190	190
Manganese	0	0.009	0.049	0.44	0.049	1.5	-	2.4	-	1.9	13	0.14	6.2	-	0.56	18000	0.21	0.44	2	2.9	5300	56	56
Mercury	0	0.0000011	0.0000011	0.0000009	0.0000011	0.0022	-	0.0005	-	0.0000035	0.000011	0.0000027	0.0062	-	<0.00001	0.1	0.000036	0.0000009	-	0.0005	0.14	0.001	0.001
Molybednum	0	0.00016	0.00051	0.00026	0.00051	0.45	-	9.8	-	0.051	0.0084	0.15	7.8	-	0.038	7.5	0.068	0.00026	-	12	140	1.9	1.9
Nickel	0	0.00022	0.00035	0.00065	0.00035	0.11	-	0.05	-	0.013	0.2	0.0023	0.32	-	0.0021	92	0.0019	0.00065	-	0.05	36	20	20
Potassium	0	0.21	0.37	0.34	0.37	-	3300	36	2600	4.7	0.0004	4.7	-	2600	31	35000	21	0.34	-	36	20000	140	140
Selenium	0	0.00014	0.00041	0.0011	0.00041	0.22	-	0.055	-	0.016	0.13	0.016	0.048	-	0.006	20	0.0034	0.0011	-	0.055	42	0.12	0.12
Silver	0	0.0000046	0.0000043	<0.000006	0.0000043	0.0022	-	0.01	-	0.00003	0.000092	0.000042	0.01	-	0.000017	0.069	0.000032	<0.000006	-	0.01	0.14	0.013	0.013
Sodium	0	2	2.4	2.5	2.4	-	45000	110	4000	8.7	0.008	9.8	-	4000	28	100000	6.9	2.5	-	130	30000	41	41
Thallium	0	0.0000056	0.0000078	0.0000073	0.0000078	0.001	-	0.00049	-	0.0008	0.0022	0.00046	0.001	-	0.000067	0.62	0.00017	0.0000073	-	0.0005	1.1	0.005	0.005
Zinc	0	0.0017	0.0032	0.0015	0.0032	0.24	-	0.97	-	0.36	2	0.0078	8.8	-	0.0029	1800	0.0046	0.0015	-	1.9	1300	170	170
Nitrate_N	0	0	-	-	0	-	-	-	4700	-	-	-	0	390	-	0	-	-	-	-	-	-	-

M:\1\01\00176\57\A\Report\5 - Closure Water Management Report\Rev 0\Appendix B\[Appendix B1.xlsx]Table 1_WQ_Source_Terms_NAB

NOTES:

1. SOURCE TERM VALUES WERE PROVIDED BY SRK (SRK 2018).

0	21SEPT'18	ISSUED WITH REPORT VA101-00176/57-5	CJ	AS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

Knight Piésold CONSULTING

TABLE B1.2

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

CLOSURE WATER QUALITY SOURCE TERMS AND ASSUMPTIONS
SOURCE TERM ASSUMPTIONS

Print: Sep/21/18 15:04:07

Flow Path	Description	Assigned Water Quality
		Open Pit
1, 5, 72	Direct Precipitation and Additional Snowblow (Pit wall runoff)	Pit wall source term based on the lithological units.
70	Evaporation	None
2	Undisturbed Surface Runoff	Non-Contact Surface Water (SFK SK100F)
3	Diversion Channel Leakage	Non-Contact Surface Water (SFK SK100F)
4	Groundwater	Groundwater (Pit area)
71	Surplus from OP WMP	Calculated Concentration in the Open Pit Water Management Pond
44	Surplus Water from Bulk TSF Main SCP	Calculated Concentration in the Main Embankment Seepage Collection Pond
64	Pyritic Tailings Re-Slurry Make-up Water from Open Pit	Calculated Concentration in Open Pit after losses
65	Pyritic Tailings Re-Slurry Water to Open Pit	Calculated Concentration in Pyritic TSF (assuming full mixing)
67	PAG Waste Rock Void Losses in the Open Pit	Calculated Concentrations in the Open Pit
68	Pyritic Tailings Void Losses in the Open Pit	Calculated Concentrations in the Open Pit
57, 62, 73, 74	Reject Flows from WTP's	WTP's - Sludge and Reject Concentrations
	Exposed Waste Rock	High Pyritic Taillings (From the Start of Backfilling in Open Pit)
	PAG Waste Rock (submerged)	PAG WR 41% of Facility Area (Before the Start of Backfilling in Open Pit)
		Water Treatment Plant #3 (WTP#3)
16	Water in Concentrate	Combined Concentrations after applying Tailings Pond Adjustment (Pond)
15	Reclaim Water from Main WMP	Concentration in the Main Water Management Pond
		Bulk Tailings Management Facility (Bulk TSF)
30	Direct Precipitation on Supernatant Pond	Direct Precipitation
35	Evaporation	None
17	Bulk Tailings Slurry Water	Calculated Concentrations in the Mill after applying Tailings Pond Adjustment (Pond)
34, 69	Bulk Tailings Beach Runoff	Quarried Rock Fill (Dams) (Non-Acidic) during reclamation (Closure Year 1 - Closure Year 10) and Non Contact Surface Water (NFK (NK119A)) after reclamation completed (Closure Year 11 onwards)
33	Recycle from Southeast Seepage Collection Pond Recycle	Concentration in the Seepage Collection Pond
45	Undisturbed Runoff	Non-Contact Surface Water (NFK (NK119A))
45	Seepage	Concentration in the Bulk TSF
46	Diversion Channel Leakage	Non-Contact Surface Water (NFK (NK119A))
47	Bulk TSF South Embankment Runoff	Quarried Rock Fill (Dams) (Non-Acidic)
75	Seepage through South Embankment	Rougher Tailings Sand Wedge (Seepage)
77	Tailings Consolidation Seepage	Calculated Concentrations within the Bulk TSF Voids
		Bulk TSF Main Embankment Seepage Collection Pond (Bulk TSF Main SCP)
39	Direct Precipitation	Direct Precipitation
43	Evaporation	None
40	Undisturbed Surface Runoff	Non-Contact Surface Water (NFK (NK119A))
41	Diversion Channel Leakage	Non-Contact Surface Water (NFK (NK119A))
37	Seepage through main Embankment	Rougher Tailings Sand Wedge (Seepage)
42	Bulk TSF Main Embankment Runoff	Quarried Rock Fill (Dams) (Non-Acidic)
76	Seepage through south and east Embankments	Rougher Tailings Sand Wedge (Seepage)
		Pyritic Tailings and PAG Waste Rock Management Facility (Pyritic TSF)
22	Direct Precipitation	Direct Precipitation
26	Evaporation	None
24	Diversion Channel Leakage	Non-Contact Surface Water (NFK (NK119A))
66	Pyritic Tailings Re-Slurry Make-up Water from Main WMP	Concentration in the Main WMP
64	Re-slurry makeup from Open Pit	Calculated Concentrations in the Open Pit
27	Pyritic Tailings Void Losses	Calculated Concentrations in the Mill after applying Tailings Pond Adjustment (Pond) to the Pyritic Slurry and WTP Rejects
28	PAG Waste Rock Voids	Calculated Concentrations in the Mill after applying Tailings Pond Adjustment (Pond) to the Pyritic Slurry and WTP Rejects
		Main Water Management Pond (Main WMP)
48	Direct Precipitation	Direct Precipitation
53	Evaporation	None
49	Undisturbed Surface Runoff	Non-Contact Surface Water (NFK (NK119A))
21	Blow Down Water to Main WMP	Outflow Concentration from WTP#2
51	Mill Site Runoff	Quarried Rock Fill (Dams) (Non Acidic)
20	Evaporation	None
19	Cooling Tower Evaporation	Outflow Concentration from WTP#2
		Water Treatment Plant # 2 (WTP#2)
54	Surplus Water from Main WMP	Calculated Concentration in the Main Water Management Pond
57	Reject Flows	WTP#2 - Sludge and Reject Concentrations
		To Environment
58 and 63	Treated Water to Environment	Outflow Concentration from WTP#1, WTP#2, and WTP#3
61	Diversion Channel to Environment	Non-Contact Surface Water (NFK (NK119A)/SFK (SK100F))
59+60	Quarry Diversions to Environment	Quarried Rock Fill (Dams) (Non Acidic)

M:\1\01\00176\57\A\Report\5 - Closure Water Management Report\Rev 0\Appendix B\[Appendix B1.xlsx]Table 2_WQ_Source_Term_Assump

NOTES:
1. FLOW PATH NUMBERING AND DESCRIPTION WERE BASED ON THE FIGURE A.1 TO A.4 AND TABLE A.1.
2. WATER QUALITY WAS BASED ON 95th PERCENTILE SOURCE TERMS PROVIDED BY SRK (2018).
3. MODEL ASSUMES RETURN OF SLUDGE, REJECT AND OUTFLOW CONCENTRATIONS WERE PROVIDED BY HDR (2018).

0	21SEPT'18	ISSUED WITH REPORT VA101-00176/57-5	CJ	AS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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TABLE B1.3

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

CLOSURE WATER QUALITY SOURCE TERMS AND ASSUMPTIONS
WATER TREATMENT PLANT CONCENTRATIONS

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Parameters	Units	WTP Sludge	WTP Reject	WTP Outflows
pH	-	-	-	7
TDS	mg/l	15452	260000	467
Alkalinity	mg/l	0	0	21
Acidity	mg/l	0	0	0
Chloride	mg/l	4	0	4.8
Fluoride	mg/l	0.31	13.7	0.4
Sulfate	mg/l	11520	181744	151
Aluminum	mg/l	3	5.55	0.0083
Antimony	mg/l	0.572	1.332	0.0034
Arsenic	mg/l	0.728	1.665	0.0042
Barium	mg/l	0.147	6.464	0.058
Berylium	mg/l	0.002	0.222	0.0012
Bismuth	mg/l	0.54	0	0.000007
Boron	mg/l	0.81	7.52	5.3
Cadmium	mg/l	0.19	0.027754	0.000049
Calcium	mg/l	3232	11698.1	45.7
Chromium	mg/l	0.029	0.13	0.0002
Cobalt	mg/l	0.766	1.64	0.0038
Copper	mg/l	1.209	0	1.2E-13
Iron	mg/l	557	0	0.000045
Lead	mg/l	0.084	0	0.000024
Magnesium	mg/l	113	1070.2	5
Manganese	mg/l	13.4	1.010263	0.0016
Mercury	mg/l	0.0059	2.89E-14	0.0000061
Molybednum	mg/l	15.7	0.55509	0.005
Nickel	mg/l	0.311	0.088814	0.0001
Potassium	mg/l	71.6	38867	29.4
Selenium	mg/l	0.097	0.55509	0.005
Silver	mg/l	0.015	0.000000118	1.9E-10
Sodium	mg/l	440	30235	183
Thallium	mg/l	0.0013	0.0029	0.0000045
Silicon	mg/l	56	4970	22.1
Tin	mg/l	0.26	0.0082	0.000015
Vanadium	mg/l	0.48	2.0649	0.0048
Zinc	mg/l	8.2	0.1998	0.00032
Nitrate_N	mg/l	9.34	3.28	7.3
Nitrate	mg/l	0.61	1.59	1
Nitrite	mg/l	0.0122	0.0318	0.01
Ammonia	mg/l	4.7	377.22	1.1

M:\1\01\00176\57\A\Report\5 - Closure Water Management Report\Rev 0\Appendix B\[Appendix B1.xlsx]Table 3_WTP_Effluent

NOTES:

1. SOURCE HDR 2018.

0	21SEPT'18	ISSUED WITH REPORT VA101-00176/57-5	CJ	AS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

Appendix B2

Water Quality Model Results

(Tables B2.1 to B2.4)

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TABLE B2.1

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

WATER QUALITY RESULTS - CLOSURE PHASE 1
50TH PERCENTILE

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Parameters	Units	Most Stringent Water Quality Standards in Receiving Water Body	WTP#2 Inflows	Bulk TSF	Main Embankment Seepage Collection Pond	Pyritic TSF	Main Water Management Pond	Open Pit
			Maximum Monthly	Maximum Monthly	Maximum Monthly	Maximum Monthly	Maximum Monthly	Maximum Monthly
pH	-	7 to 7.5	-	-	-	-	-	-
TDS	mg/l	500	669	484	2,472	2,708	669	2,706
Alkalinity	mg/l	20	121	81	453	216	121	145
Chloride	mg/l	230.00	1.96	3.93	8.55	7.42	1.96	5.8
Fluoride	mg/l	1.00	0.15	0.11	0.83	0.48	0.15	0.38
Sulfate	mg/l	250	372	269	1,374	1,687	372	1,744
Aluminum	mg/l	0.0870	0.3480	0.0006	1.47	0.0006	0.3480	0.0
Antimony	mg/l	0.006	0.0292	0.0079	0.1169	0.0671	0.0292	0.07
Arsenic	mg/l	0.010	0.0385	0.0100	0.1520	0.1145	0.0385	0.109
Barium	mg/l	2.000	0.025	0.016	0.088	0.108	0.025	0.106
Berylium	mg/l	0.0040	0.00171	0.00862	0.00293	0.00830	0.00171	0.00684
Bismuth	mg/l	-	0.0148	0.0023	0.0585	0.0598	0.0148	0.061
Boron	mg/l	0.75	0.080	0.052	0.304	0.221	0.080	0.21
Cadmium	mg/l	0.0001	0.00247	0.00352	0.00585	0.05362	0.00247	0.042
Calcium	mg/l	-	118	54	451	377	118	395
Chromium	mg/l	0.019	0.0030	0.0010	0.0117	0.0060	0.0030	0.0055
Cobalt	mg/l	0.050	0.0108	0.0083	0.0292	0.2191	0.0108	0.18
Copper	mg/l	0.002	0.0508	0.0022	0.2163	0.0100	0.0508	0.01
Iron	mg/l	1.000	0.280	0.002	1.655	0.002	0.280	0.0
Lead	mg/l	0.001	0.0077	0.0054	0.0293	0.0185	0.0077	0.0164
Magnesium	mg/l	-	17	25	58.0	43	17	38
Manganese	mg/l	0.05	0.47	0.38	1.70	2.00	0.47	2.0
Mercury	mg/l	0.00001	0.000090	0.000029	0.000293	0.001466	0.000090	0.00113
Molybednum	mg/l	0.010	1.7000	0.3175	7.0130	2.2870	1.7000	2.1
Nickel	mg/l	0.013	0.0107	0.0242	0.0293	0.0952	0.0107	0.086
Potassium	mg/l	-	8.2	15.2	21.1	127.6	8.2	133
Selenium	mg/l	0.005	0.0086	0.0063	0.0322	0.0270	0.0086	0.0278
Silver	mg/l	0.0011	0.001429	0.000269	0.005845	0.002711	0.001429	0.0023
Sodium	mg/l	-	25	33	76	229	25	224
Thallium	mg/l	0.00170	0.00010	0.00018	0.00029	0.00049	0.00010	0.00049
Silicon	mg/l	-	7	3	29	21	7	22
Tin	mg/l	-	0.0282	0.0069	0.1169	0.0246	0.0282	0.0247
Vanadium	mg/l	0.100	0.0049	0.0012	0.0176	0.0404	0.0049	0.0432
Zinc	mg/l	0.03	0.341	0.473	1.111	2.368	0.341	2.0
Nitrate_N	mg/l	1.0	0	0	0	1	0	0.9
Nitrate (ion)	mg/l	-	0	1	0	1	0	0.9
Nitrite	mg/l	1.00	0.00	0.03	0.00	0.02	0.00	0.02
Ammonia	mg/l	4.36	0.0	0.1	0.0	1.4	0.0	1.47
Hardness as $CaCO_3$	mg/l	100	363	239	1,365	1,117	363	1,141

M:\1\01\00176\57\A\Report\5 - Closure Water Management Report\Rev 0\Appendix B\[Appendix B2.xlsx]Table1_Preliminary_WQ

NOTES:

1. MODEL INPUT CONCENTRATIONS PROVIDED BY SRK CONSULTING (SRK 2018).
2. TAILINGS POND ADJUSTMENT VALUES WERE APPLIED FOR Al, SO4, Fe, Cu and Mn IN THE BULK TSF AND PYRITIC TSF.
3. TDS VALUES WERE CALCULATED BY SUMMING ALKALINITY, Cl, F, SO_4, Ca, Mg, K, Na AND Si.
4. MODEL ASSUMES RETURN OF SLUDGE AND REJECT FLOWS FROM WTP#2 AND WTP#3 TO THE OPEN PIT.
5. WTP EFFLUENT, SLUDGE AND REJECT CONCENTRATIONS WERE PROVIDED BY HDR (HDR 2018).
6. HARDNESS VALUES WERE CALCULATED BASED ON THE EQUATION
   HARDNESS ($CaCO_3$) = CALCIUM CONCENTRATION (mg/L)*2.497+MAGNESSIUM CONCENTRATION (mg/L)*4.118
7. THE PERCENTILE RESULTS BASED ON 76 REALIZATIONS OF MODEL SIMULATIONS.
8. MODEL ASSUMES THE LOADING FROM THE PAG WASTE ROCK IN THE PYRITIC TSF AND OPEN PIT AS A FLUSHING TERM PROVIDED BY SRK CONSULTING (SRK 2018).
9. pH WAS NOT MODELLED.
10. HIGHLIGHTED CELLS REPRESENT PREDICTED CONCENTRATIONS EXCEEDS THE DISCHARGE WATER QUALITY CRITERIA.

0	21SEP'18	ISSUED WITH REPORT VA101-176/57-5	ELK	AS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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TABLE B2.2

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

WATER QUALITY RESULTS - CLOSURE PHASE 2
50TH PERCENTILE

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Parameters	Units	Most Stringent Water Quality Standards in Receiving Water Body	WTP#2 Inflows	Bulk TSF	Main Embankment Seepage Collection Pond	Open Pit
			Maximum Monthly	Maximum Monthly	Maximum Monthly	Maximum Monthly
pH	-	7 to 7.5	-	-	-	-
TDS	mg/l	500	0	2,518	3,610	1,347
Alkalinity	mg/l	20	0	327	665	153
Chloride	mg/l	230.00	0.00	8.16	8.05	3.2
Fluoride	mg/l	1.00	0.00	0.56	0.78	0.27
Sulphate	mg/l	250	0	1,491	2,029	814
Aluminum	mg/l	0.0870	0.0000	0.0006	2.1600	0.0
Antimony	mg/l	0.006	0.0000	0.0927	0.1727	0.047
Arsenic	mg/l	0.010	0.0000	0.1173	0.2245	0.063
Barium	mg/l	2.000	0.000	0.066	0.130	0.049
Berylium	mg/l	0.0040	0.00000	0.01122	0.00432	0.00269
Bismuth	mg/l	-	0.0000	0.0614	0.0863	0.031
Boron	mg/l	0.75	0.000	0.315	0.449	0.15
Cadmium	mg/l	0.0001	0.00000	0.00634	0.00863	0.009
Calcium	mg/l	-	0	473	665	234
Chromium	mg/l	0.019	0.0000	0.0124	0.0173	0.0054
Cobalt	mg/l	0.050	0.0000	0.0332	0.0432	0.05
Copper	mg/l	0.002	0.0000	0.0100	0.3195	0.01
Iron	mg/l	1.000	0.000	0.002	1.559	0.0
Lead	mg/l	0.001	0.0000	0.0316	0.0432	0.0138
Magnesium	mg/l	-	0	75	85.5	29
Manganese	mg/l	0.05	0.00	1.60	2.50	1.3
Mercury	mg/l	0.00001	0.000000	0.000310	0.000432	0.0003
Molybednum	mg/l	0.010	0.0000	6.0310	10.3600	2.6
Nickel	mg/l	0.013	0.0000	0.0498	0.0432	0.03
Potassium	mg/l	-	0.0	33.4	31.1	35
Selenium	mg/l	0.005	0.0000	0.0349	0.0475	0.0194
Silver	mg/l	0.0011	0.000000	0.006144	0.008634	0.0025
Sodium	mg/l	-	0	89	112	66
Thallium	mg/l	0.00170	0.00000	0.00043	0.00043	0.00024
Silicon	mg/l	-	0	21	14	12
Tin	mg/l	-	0.0000	0.1170	0.1727	0.0466
Vanadium	mg/l	0.100	0.0000	0.0186	0.0259	0.0148
Zinc	mg/l	0.03	0.000	0.969	1.641	0.6
Nitrate_N	mg/l	1.0	0	0	0	0.2
Nitrate (ion)	mg/l	-	0	1	0	0.2
Nitrite	mg/l	1.00	0.00	0.03	0.00	0.0
Ammonia	mg/l	4.36	0.0	0.1	0.0	0.31
Hardness as $CaCO_3$	mg/l	100	0	1,493	2,012	704

M:\1\01\00176\57\A\Report\5 - Closure Water Management Report\Rev 0\Appendix B\[Appendix B2.xlsx]Table2_Preliminary_WQ

NOTES:

1. MODEL INPUT CONCENTRATIONS PROVIDED BY SRK CONSULTING (SRK 2018).
2. TAILINGS POND ADJUSTMENT VALUES WERE APPLIED FOR Al, SO4, Fe, Cu and Mn IN THE BULK TSF AND PYRITIC TSF.
3. TDS VALUES WERE CALCULATED BY SUMMING ALKALINITY, Cl, F, SO4, Ca, Mg, K, Na AND Si.
4. MODEL ASSUMES RETURN OF SLUDGE AND REJECT FLOWS FROM WTP#2 AND WTP#3 TO THE OPEN PIT.
5. WTP EFFLUENT, SLUDGE AND REJECT CONCENTRATIONS WERE PROVIDED BY HDR (HDR 2018).
6. HARDNESS VALUES WERE CALCULATED BASED ON THE EQUATION
   HARDNESS (CaCO3) = CALCIUM CONCENTRATION (mg/L)*2.497+MAGNESSIUM CONCENTRATION (mg/L)*4.118
7. THE PERCENTILE RESULTS BASED ON 76 REALIZATIONS OF MODEL SIMULATIONS.
8. MODEL ASSUMES THE LOADING FROM THE PAG WASTE ROCK IN THE PYRITIC TSF AND OPEN PIT AS A FLUSHING TERM PROVIDED BY SRK CONSULTING (SRK 2018).
9. pH WAS NOT MODELLED.
10. HIGHLIGHTED CELLS REPRESENT PREDICTED CONCENTRATIONS EXCEEDS THE DISCHARGE WATER QUALITY CRITERIA.

0	21SEP'18	ISSUED WITH REPORT VA101-176/57-5	ELK	AS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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TABLE B2.3

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

WATER QUALITY RESULTS - CLOSURE PHASE 3
50TH PERCENTILE

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Parameters	Units	Most Stringent Water Quality Standards in Receiving Water Body	Bulk TSF	Main Embankment Seepage Collection Pond	Open Pit	WTP#3 Inflows
			Maximum Monthly	Maximum Monthly	Maximum Monthly	Maximum Monthly
pH	-	7 to 7.5	-	-	-	-
TDS	mg/l	500	204	1,750	1030	1107
Alkalinity	mg/l	20	42	322	53	100
Chloride	mg/l	230.00	1.97	3.95	1.5	1.6
Fluoride	mg/l	1.00	0.06	0.38	0.13	0.15
Sulphate	mg/l	250	102	978	685	700
Aluminum	mg/l	0.0870	0.0006	1.0450	0.0	0.12
Antimony	mg/l	0.006	0.0030	0.0832	0.028	0.036
Arsenic	mg/l	0.010	0.0034	0.1082	0.036	0.047
Barium	mg/l	2.000	0.008	0.063	0.03	0.031
Berylium	mg/l	0.0040	0.00326	0.00208	0.00126	0.00128
Bismuth	mg/l	-	0.0010	0.0416	0.021	0.024
Boron	mg/l	0.75	0.021	0.217	0.07	0.09
Cadmium	mg/l	0.0001	0.00134	0.00416	0.007	0.007
Calcium	mg/l	-	23	321	155	168
Chromium	mg/l	0.019	0.0005	0.0084	0.0025	0.0033
Cobalt	mg/l	0.050	0.0032	0.0208	0.03	0.03
Copper	mg/l	0.002	0.0010	0.1540	0.01	0.03
Iron	mg/l	1.000	0.002	0.768	0.0	0.1
Lead	mg/l	0.001	0.0022	0.0208	0.006	0.0083
Magnesium	mg/l	-	10	41.3	12	16
Manganese	mg/l	0.05	0.15	1.21	0.9	0.9
Mercury	mg/l	0.00001	0.000012	0.000208	0.00021	0.00021
Molybednum	mg/l	0.010	0.1218	4.9940	1.1	1.8
Nickel	mg/l	0.013	0.0093	0.0208	0.018	0.019
Potassium	mg/l	-	5.8	15.0	50	49
Selenium	mg/l	0.005	0.0025	0.0229	0.0104	0.012
Silver	mg/l	0.0011	0.000107	0.004162	0.001	0.0016
Sodium	mg/l	-	14	54	59	59
Thallium	mg/l	0.00170	0.00007	0.00021	0.00014	0.00014
Silicon	mg/l	-	5	14	13	13
Tin	mg/l	-	0.0026	0.0832	0.0188	0.0291
Vanadium	mg/l	0.100	0.0007	0.0125	0.0175	0.0174
Zinc	mg/l	0.03	0.180	0.791	0.4	0.4
Nitrate_N	mg/l	1.0	0	0	0.3	0.3
Nitrate (ion)	mg/l	-	1	0	0.1	0.1
Nitrite	mg/l	1.00	0.01	0.00	0.0	0.0
Ammonia	mg/l	4.36	0.0	0.0	0.57	0.55
Hardness as $CaCO_3$	mg/l	100	99	971	438	488

M:\1\01\00176\57\A\Report\5 - Closure Water Management Report\Rev 0\Appendix B\[Appendix B2.xlsx]Table 3_Preliminary_WQ

NOTES:

1. MODEL INPUT CONCENTRATIONS PROVIDED BY SRK CONSULTING (SRK 2018).
2. TAILINGS POND ADJUSTMENT VALUES WERE APPLIED FOR Al, SO4, Fe, Cu and Mn IN THE BULK TSF AND PYRITIC TSF.
3. TDS VALUES WERE CALCULATED BY SUMMING ALKALINITY, Cl, F, SO4, Ca, Mg, K, Na AND Si.
4. MODEL ASSUMES RETURN OF SLUDGE AND REJECT FLOWS FROM WTP#2 AND WTP#3 TO THE OPEN PIT.
5. WTP EFFLUENT, SLUDGE AND REJECT CONCENTRATIONS WERE PROVIDED BY HDR (HDR 2018).
6. HARDNESS VALUES WERE CALCULATED BASED ON THE EQUATION
   HARDNESS (CaCO3) = CALCIUM CONCENTRATION (mg/L)*2.497+MAGNESSIUM CONCENTRATION (mg/L)*4.118
7. THE PERCENTILE RESULTS BASED ON 76 REALIZATIONS OF MODEL SIMULATIONS.
8. MODEL ASSUMES THE LOADING FROM THE PAG WASTE ROCK IN THE PYRITIC TSF AND OPEN PIT AS A FLUSHING TERM PROVIDED BY SRK CONSULTING (SRK 2018).
9. pH WAS NOT MODELLED.
10. HIGHLIGHTED CELLS REPRESENT PREDICTED CONCENTRATIONS EXCEEDS THE DISCHARGE WATER QUALITY CRITERIA.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	21SEP'18	ISSUED WITH REPORT VA101-176/57-5	ELK	AS

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TABLE B2.4

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

WATER QUALITY RESULTS - POST CLOSURE (PHASE 4)
50TH PERCENTILE

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Parameters	Units	Most Stringent Water Quality Standards in Receiving Water Body	Bulk TSF	Main Embankment Seepage Collection Pond	Open Pit	WTP#3 Inflows
			Maximum Monthly	Maximum Monthly	Maximum Monthly	Maximum Monthly
pH	-	7 to 7.5	-	-	-	-
TDS	mg/l	500	28	4,036	853	1917
Alkalinity	mg/l	20	14	741	23	361
Chloride	mg/l	230.00	0.61	8.95	1.0	3.6
Fluoride	mg/l	1.00	0.03	0.87	0.08	0.34
Sulphate	mg/l	250	1	2,260	586	1074
Aluminum	mg/l	0.0870	0.0006	2.4050	0.0	0.85
Antimony	mg/l	0.006	0.0001	0.1923	0.02	0.075
Arsenic	mg/l	0.010	0.0001	0.2500	0.026	0.098
Barium	mg/l	2.000	0.002	0.144	0.024	0.059
Berylium	mg/l	0.0040	0.00001	0.00481	0.0007	0.0019
Bismuth	mg/l	-	0.0001	0.0962	0.017	0.047
Boron	mg/l	0.75	0.002	0.500	0.04	0.2
Cadmium	mg/l	0.0001	0.00001	0.00962	0.006	0.007
Calcium	mg/l	-	4	741	120	301
Chromium	mg/l	0.019	0.0002	0.0192	0.0015	0.0075
Cobalt	mg/l	0.050	0.0001	0.0481	0.03	0.04
Copper	mg/l	0.002	0.0004	0.3558	0.01	0.12
Iron	mg/l	1.000	0.002	1.733	0.0	0.6
Lead	mg/l	0.001	0.0002	0.0481	0.0033	0.0188
Magnesium	mg/l	-	1	95.2	7	37
Manganese	mg/l	0.05	0.01	2.79	0.8	1.4
Mercury	mg/l	0.00001	0.000001	0.000481	0.00018	0.00027
Molybednum	mg/l	0.010	0.0002	11.5400	0.6	5.6
Nickel	mg/l	0.013	0.0002	0.0481	0.015	0.025
Potassium	mg/l	-	0.2	34.6	51	47
Selenium	mg/l	0.005	0.0001	0.0529	0.0076	0.0208
Silver	mg/l	0.0011	0.000005	0.009616	0.0005	0.0047
Sodium	mg/l	-	2	125	53	74
Thallium	mg/l	0.00170	0.00001	0.00048	0.00011	0.00022
Silicon	mg/l	-	5	31	12	18
Tin	mg/l	-	0.0001	0.1923	0.0096	0.0751
Vanadium	mg/l	0.100	0.0003	0.0289	0.0168	0.0203
Zinc	mg/l	0.03	0.002	1.827	0.3	0.7
Nitrate_N	mg/l	1.0	0	0.00	0.3	0.2
Nitrate (ion)	mg/l	-	0	0.00	0.035	0.029
Nitrite	mg/l	1.00	0.00	0.00	0.00071	0.00059
Ammonia	mg/l	4.36	0.0	0.00	0.6	0.5
Hardness as $CaCO_3$	mg/l	100	12	2,241	328	905

M:\1\01\00176\57\A\Report\5 - Closure Water Management Report\Rev 0\Appendix B\[Appendix B2.xlsx]Table 4_Preliminary_WQ

NOTES:

1. MODEL INPUT CONCENTRATIONS PROVIDED BY SRK CONSULTING (SRK 2018).
2. TAILINGS POND ADJUSTMENT VALUES WERE APPLIED FOR Al, SO4, Fe, Cu and Mn IN THE BULK TSF AND PYRITIC TSF.
3. TDS VALUES WERE CALCULATED BY SUMMING ALKALINITY, Cl, F, SO4, Ca, Mg, K, Na AND Si.
4. MODEL ASSUMES RETURN OF SLUDGE AND REJECT FLOWS FROM WTP#2 AND WTP#3 TO THE OPEN PIT.
5. WTP EFFLUENT, SLUDGE AND REJECT CONCENTRATIONS WERE PROVIDED BY HDR (HDR 2018).
6. HARDNESS VALUES WERE CALCULATED BASED ON THE EQUATION
   HARDNESS (CaCO3) = CALCIUM CONCENTRATION (mg/L)*2.497+MAGNESSIUM CONCENTRATION (mg/L)*4.118
7. THE PERCENTILE RESULTS BASED ON 76 REALIZATIONS OF MODEL SIMULATIONS.
8. MODEL ASSUMES THE LOADING FROM THE PAG WASTE ROCK IN THE PYRITIC TSF AND OPEN PIT AS A FLUSHING TERM PROVIDED BY SRK CONSULTING (SRK 2018).
9. pH WAS NOT MODELLED.
10. HIGHLIGHTED CELLS REPRESENT PREDICTED CONCENTRATIONS EXCEEDS THE DISCHARGE WATER QUALITY CRITERIA.

0	21SEP'18	ISSUED WITH REPORT VA101-176/57-5	ELK	AS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

Prepared for
Pebble Limited Partnership
3201 C Street, Suite 505
Anchorage, Alaska
USA, 99503

Prepared by
Knight Piésold Ltd.
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Vancouver, British Columbia
Canada, V6C 2T8

Project Number
VA101-176/57-4

PEBBLE PROJECT
PEBBLE MINE SITE
OPERATIONS WATER MANAGEMENT PLAN

Rev	Description	Date
0	Issued in Final	July 6, 2018
1	Updated with Client Comments	July 6, 2018

Knight Piésold CONSULTING

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ABBREVIATIONS

Pebble Project	the Project
ADSP	Alaska Dam Safety Program
Bulk TSF	Bulk Tailings Storage Facility
Bulk TSF Main SCP	Bulk TSF Main Embankment Seepage Collection Pond
IDF	Inflow Design Flood
Main WMP	Main Water Management Pond
NFK	North Fork Koktuli
NOAA	National Oceanic and Atmospheric Administration
NWS	US National Weather Service
OP WMP	Open Pit Water Management Pond
PAG	Potentially Acid Generating
PLP	Pebble Limited Partnership
Pyritic TSF	Pyritic Tailings and Potentially Acid Generating Waste Rock Storage Facility
RO	reverse osmosis
SFK	South Fork Koktuli
TDS	Total dissolved solids
tpd	tons per day
TSF	Tailings Storage Facility
USGS	United States Geological Survey
UT	Upper Talarik

1.0 INTRODUCTION

1.1 PEBBLE PROJECT OVERVIEW

The Pebble Project (the Project) is a proposed mining development of a copper-gold-molybdenum deposit located approximately 238 miles southwest of Anchorage, Alaska, and 17 miles northwest of the village of Iliamna. The deposit is situated on a drainage divide at the headwaters of three waterways, with the Upper Talarik (UT) draining to the east, and the North Fork Koktuli (NFK) and South Fork Koktuli (SFK) draining to the west and southwest, respectively.

The deposit will be mined by open pit methods feeding an associated process plant with a throughput capacity of 180,000 tons per day (tpd), over an operating life of 20 years. The milling process produces two streams of tailings; a bulk tailings stream and a pyritic tailings stream. The Bulk Tailings Storage Facility (Bulk TSF) will manage non potentially acid generating tailings (bulk tailings), and the Pyritic Tailings Storage Facility (Pyritic TSF) will manage pyritic tailings, which are assumed to be Potentially Acid Generating (PAG), and PAG waste rock from the mining activities.

The Project includes the following key water management facilities: fresh water diversion channels, the Open Pit Water Management Pond (OP WMP), the Main Water Management Pond (Main WMP), the Bulk and Pyritic TSF's, the Bulk TSF Main Embankment Seepage Collection Pond (Bulk TSF Main SCP), seepage collection and recycle ponds, sediment ponds, and two water treatment plants (WTP#1 and WTP#2). The Project general arrangement, showing the locations of the TSF's and water management facilities, is presented on Figure 1.1.

The Bulk TSF will manage approximately 1.1 billion tons of bulk tailings solids. The main embankment of the Bulk TSF is proposed to operate as a drained facility to promote long term drainage of the bulk tailings mass. The Bulk TSF Main SCP, which is located downstream of the main embankment of the Bulk TSF, will collect seepage that passes through the main embankment. Water collected in the Bulk TSF Main SCP will be pumped to the Main WMP. The Bulk TSF south embankment is proposed to include a hydraulic barrier, consisting of a HDPE liner or a low permeability core zone, and a grout curtain installed in the weathered bedrock of the foundation. A seepage collection pond will be located downstream of the south embankment to collect any potential seepage and embankment runoff. A seepage collection pond will also be constructed along the east side of the Bulk TSF to collect potential seepage and runoff from the east side of the facility. Water collected in the seepage collection ponds to the south and east of the Bulk TSF will be pumped back to the Bulk TSF.

The Pyritic TSF will manage approximately 150 million tons of pyritic tailings and 126 million tons of PAG waste rock, stored sub-aqueously. The Pyritic TSF is a lined facility and will include an underdrain to convey groundwater and potential seepage from the facility to a seepage collection pond at the north end of the facility. Water (groundwater, seepage and surface runoff) collected in the seepage collection pond will be pumped to the Main WMP.

Construction materials are proposed to be primarily sourced from three quarries located around the Bulk TSF, as shown on Figure 1.1. Construction materials for the various embankments will be sourced from

Quarry A, Quarry B and Quarry C, with additional non-PAG materials sourced from Open Pit stripping activities, as available. Quarry A will be active during the pre-mining phase (construction) and during operations until the tailings level in the Bulk TSF inundates the quarry. Ongoing construction materials will be sourced from Quarry B, Quarry C, and Open Pit stripping (as required) throughout operations.

Hydraulic confinement of the Bulk TSF will be achieved and maintained using a series of seepage control measures including grout cut-off walls and seepage pump-back systems. Confinement will be monitored based on groundwater levels and quality in installed wells. The quarries developed on the perimeter of the TSF will be designed to maintain a groundwater level above the elevation of the supernatant pond, thereby preventing the seepage of pond water into the quarries.

Surplus water collected within the Project footprint (surface runoff and groundwater) that is not required to supply the milling process will be treated and released. Water stored in the Main WMP will be used to supply the process during prolonged dry periods. Discharge locations for treated water are proposed in the NFK, SFK and UT catchments, as shown on Figure 1.1. Two water treatment plants will treat surplus water from the Project site; WTP#1 is located near the Open Pit and will treat water from the OP WMP, and WTP#2 is located near the Main WMP and will treat surplus water from the Main WMP. The water treatment plants will each include pumping and piping systems configured to convey flows to all three of the discharge locations.

1.2 SCOPE OF REPORT

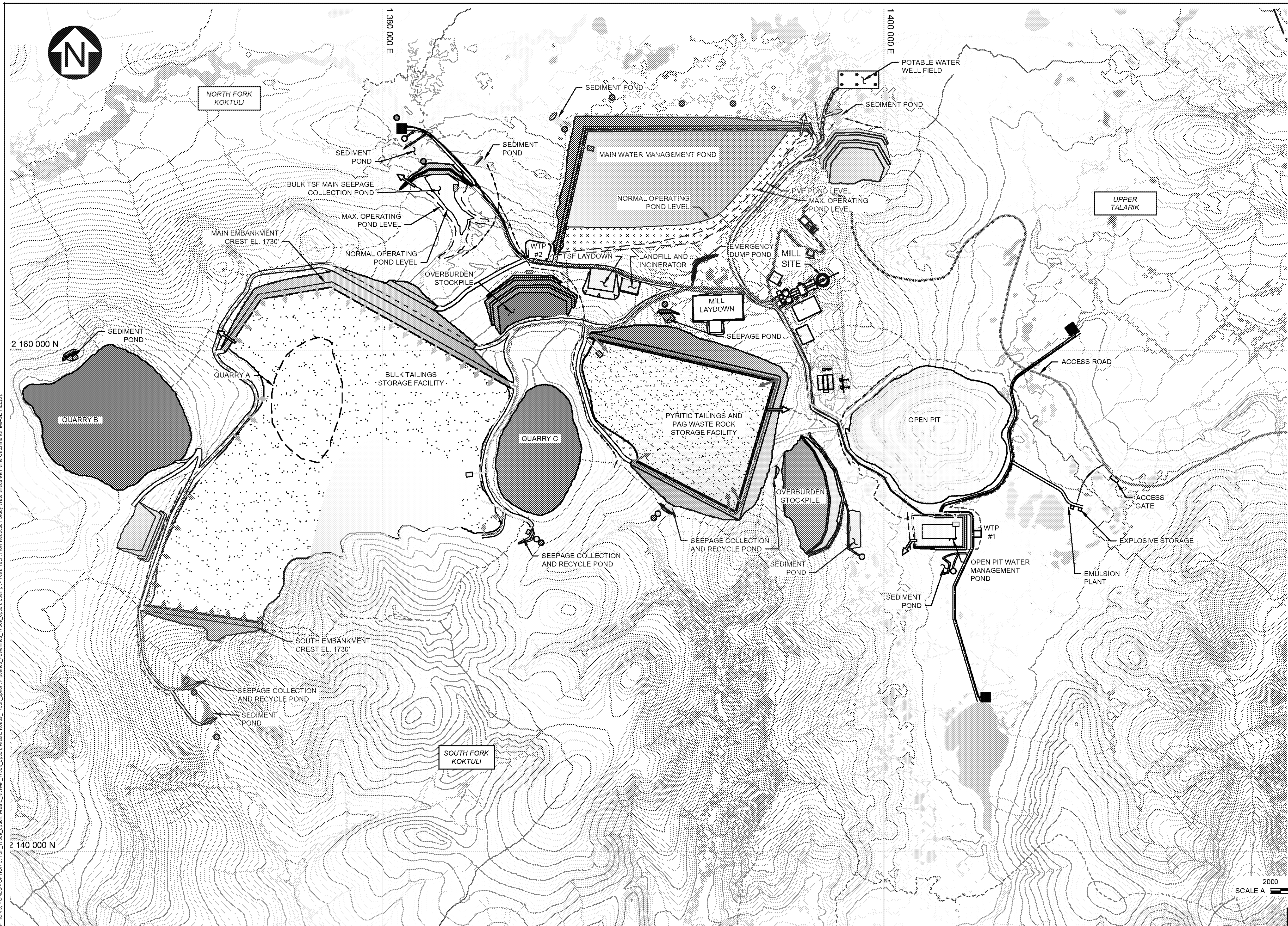
The purpose of this report is to describe the water management plan for the mine site area during operations when all of the project facilities (e.g. processing mill, water treatment plants, etc.) are operating. Normal operating conditions included consideration of climate variability scenarios. In addition to climate variability, allowances for storm storage and freeboard have been provided for all ponds and water management facilities.

A summary of the hydrometeorological and groundwater characteristics for the Pebble Project are provided within this report. A full description of the hydrometeorological conditions will be provided in the hydrometeorology report (currently in progress). A full description of the baseline groundwater conditions is presented in the 2015 Groundwater SEBD Chapter 8 (Groundwater Hydrology) and SEBD Chapter 9 (Water Quality) reports (PLP 2015a; 2015b). A description of the predicted groundwater conditions during and after mine operation will be provided in the groundwater modelling report (currently in progress). The geochemical parameters used for the development of the water quality model were provided by SRK and are summarized in their geochemical source term report (SRK 2018).

This water management report includes the following:

- Characterization of the hydrometeorological and hydrogeological setting for the mine site
- Description of how mine drainage and stormwater will be managed at the mine site
- Demonstration of adequate storage and supply of makeup water to the Process Plant over a full range of potential climate conditions, including prolonged dry and wet periods
- Identification of the surplus flows available for treatment and discharge, and

- Provision of water quality predictions for the major water management facilities and water treatment plants.



LEGEND:

- OPEN PIT
- BULK TAILINGS
- OVERBURDEN STOCKPILE
- GROWTH MEDIUM STOCKPILE
- EMBANKMENT FILL
- POND
- PYRITIC TAILINGS
- LINER
- MINERAL CLOSING ORDER
- DRAINAGE DIVIDE
- RECLAIM PIPELINE
- RECLAIM WATER PUMPING BARGE
- BULK TAILINGS PIPELINE
- BULK TAILINGS DISCHARGE
- PYRITIC TAILINGS PIPELINE
- PYRITIC TAILINGS DISCHARGE
- WTP POTABLE WATER PIPELINE
- WTP DISCHARGE PIPELINE
- NATURAL GAS PIPELINE (10 inch DIAMETER.)
- ROAD
- WTP DISCHARGE POINT
- WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING AND POTENTIAL PUMP BACK AREA
- DIVERSION CHANNEL
- COLLECTION DITCH
- EMERGENCY SPILLWAY

NOTES:

1. COORDINATE GRID IS UTM NAD83, ALASKA STATE PLANES; ZONE 5.
2. CONTOUR INTERVAL IS 25 FEET.
3. DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS NOTED OTHERWISE.
4. OPEN PIT OUTLINE PROVIDED BY PLP, JUNE 14, 2018.
5. ACCESS ROAD PROVIDED BY RECON LLC. ROAD CONNECTION TO MILL SITE COMPLETED BY AUSENCO LTD.
6. CONCEPTUAL HAUL, SERVICE, AND ACCESS ROAD CUT AND FILL EXTENTS SHOWN INCLUDE ALLOWANCE FOR BERMS, DITCHES, AND POWER POLES, AS REQUIRED.
7. ORIGINAL DRAINAGE DIVIDES PROVIDED BY HDR, JUNE 15, 2018. DRAINAGE DIVIDES HAVE BE REVISED AROUND MINE FACILITIES AS REQUIRED.

SCALE A: 2000 0 2000 4000 6000 8000 10000 ft

PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

GENERAL ARRANGEMENT MAXIMUM FOOTPRINT

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-176/57	4

FIGURE 1.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	05JUL'18	ISSUED WITH REPORT	JRG	RMM	LJG

SAVED: M:\1\01\00176\57\A\Acad\FIGS\B52, 6/29/2018 1:13:44 PM, RMCLELLAN PRINTED: 7/5/2018 4:08:56 PM, FIG 1, RMCLELLAN ACAD VERSION: 23.0S (LMS TECH)

2.0 HYDROMETEOROLOGICAL CHARACTERISTICS

2.1 OVERVIEW

The Project location and regional setting are shown on Figure 2.1. The position of the Project site relative to the three main local drainage basins (NFK, SFK, and UTC) is shown on Figure 2.2.

The locations of hydrometeorological stations in the Project area are shown on Figure 2.2. These include meteorological stations, which are discussed in Section 2.2, and streamflow gaging stations, which are discussed in Section 2.3. A spreadsheet model, referred to as the Pebble Project Watershed Module (described below), was developed to relate meteorological inputs to groundwater and surface water responses in the project. Long-term regional climate records, which were adjusted for site specific conditions, were used as input to the Watershed Module to generate long-term estimates of groundwater and streamflow conditions.

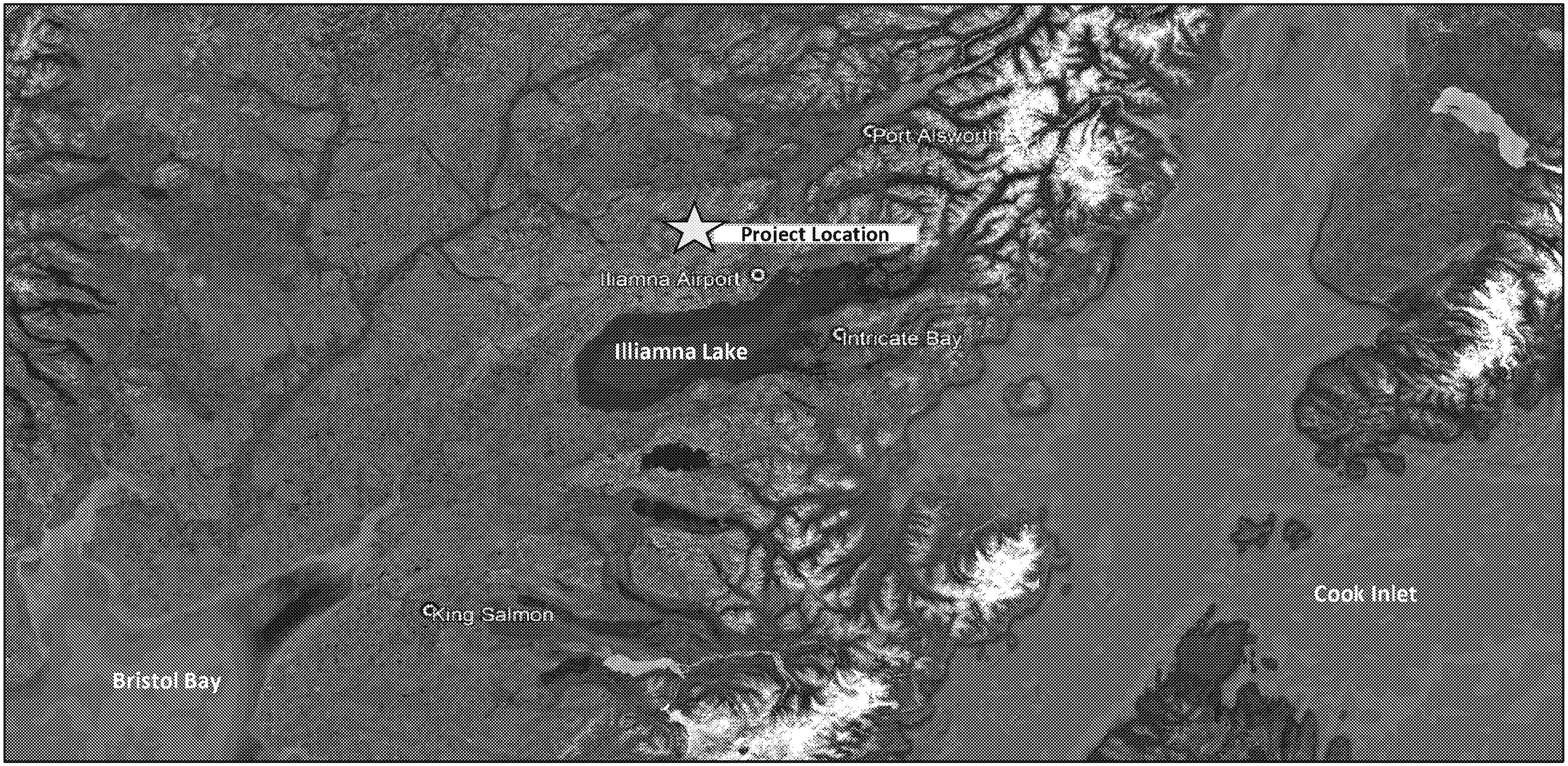
The Pebble Project Watershed Module is a numerical, semi-distributed, spreadsheet-based precipitation-runoff model that incorporates the key components of the hydrologic cycle including precipitation as rain and snow, evaporation, sublimation, runoff, surface storage, and groundwater recharge, discharge and storage.

2.2 CLIMATE CHARACTERISTICS

2.2.1 SETTING

The Project is located in a transitional climatic zone with strong maritime influences. Summer temperatures are moderated by the open waters of Iliamna Lake, the Bering Sea, and Cook Inlet. Winter temperatures are more continental because of the presence of ice on Iliamna Lake and Bristol Bay during the coldest months of the year. Winter weather systems typically travel into the region from the Bering Sea to the west, from along the Aleutian Islands chain to the southwest, and from the Gulf of Alaska to the south; as a result, winter temperatures are less influenced by Cook Inlet than summer temperatures. These weather systems consist of cool to cold air that is saturated with moisture, resulting in frequent clouds, rain, and snow. Less frequent wintertime incursions of frigid, stable arctic air masses bring shorter periods of clear and very cold conditions to the region. Incursions of very warm air masses from the interior of Alaska can cause atmospheric instability in the summer months, which results in the development of cumulus clouds and thunderstorm activity.

The mean annual temperature in the Project area is just below freezing, with freezing temperatures generally persisting from October through April, and conditions are quite wet, with mean annual precipitation varying throughout the project area but generally ranging from 45 in. to 55 in.



LEGEND:

☆ PROJECT LOCATION

◉ REGIONAL METEROLOGICAL STATION

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	05JUL'18	ISSUED WITH REPORT	CJN	JGC

PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

PROJECT LOCATION

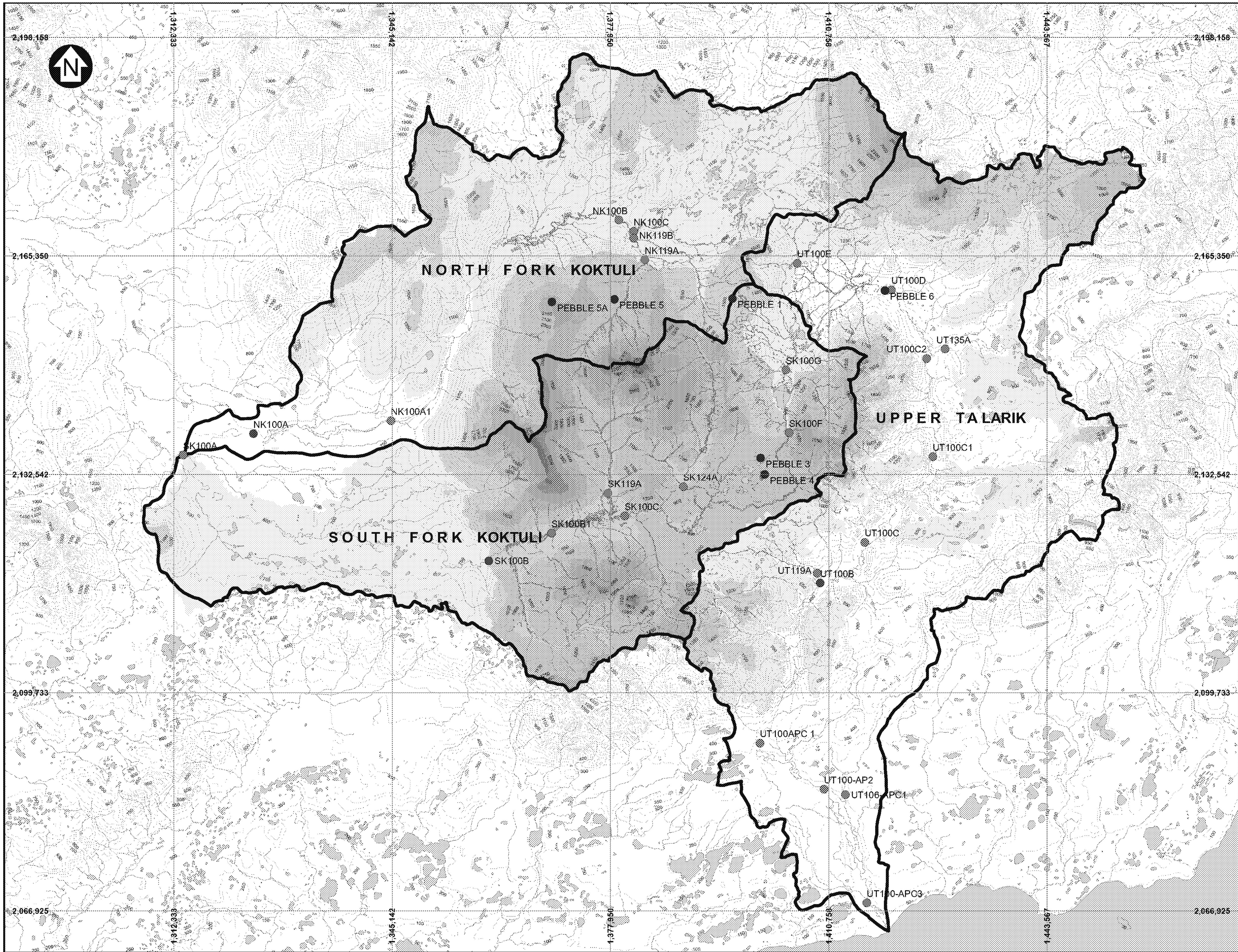
Knight Piésold CONSULTING

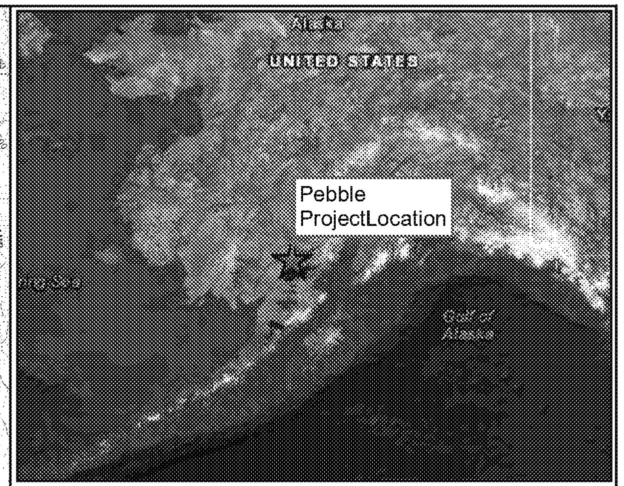
P/A NO. VA101-176/57

REF. NO. 4

FIGURE 2.1

REV 0





LEGEND:

- PLP METEOROLOGICAL STATION
- PLP STREAMFLOW GAGING STATION
- USGS STREAMFLOW GAGING STATION
- PRIMARY DRAINAGE BASIN
- LAKE/RIVER
- CONTOUR 50FT

MEAN ANNUAL PRECIPITATION (INCHES)

- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 75 - 80
- 80 - 81

NOTES:

1. BASE MAP: USGS BASE MAPPING.
2. COORDINATE GRID IS IN FEET. COORDINATE SYSTEM: NAD 1983 STATEPLANE ALASKA 5 FIPS 5005 FEET.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:50,837,317 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.
4. CONTOUR INTERVAL IS FEET.
5. PRECIPITATION VALUES INCLUDE OROGRAPHIC AND LOCATION CONSIDERATIONS AND WERE ESTIMATED USING THE PEBBLE PROJECT WATERSHED MODEL.

2 1 0 2 4 6 8 10 km

PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

DRAINAGE BASINS AND HYDROMETEROLOGICAL STATION LOCATIONS IN THE PROJECT AREA

Knight Piésold CONSULTING

P/A NO. VA101-176/57 | REF NO. 4

FIGURE 2.2 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	06JUN'18	ISSUED WITH REPORT	CJN	KK	JGC

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2.2.2 METEOROLOGICAL STATIONS

Meteorological data have been collected at six monitoring stations in the Project area. The station locations, data collection methods, and the data collected up until 2008 are presented in the Environmental Baseline Data Report (PLP 2011). The station with the longest period of record, and that which is considered most representative of conditions in the mine development area, is Pebble 1 (2005-2013, and re-started in 2017). The Pebble 1 station is situated west of the deposit at an elevation of 1,560 ft. Data collected at Pebble 1 were used for modelling long-term climatic conditions in the mine study area. Temperature and precipitation data recorded at Pebble 1 were correlated with records collected by the US National Weather Service (NWS) at Iliamna Airport, which is situated 17 miles southeast of the Project at an elevation of 190 ft. The derived relationships were used to generate a long-term synthetic series of monthly temperature and precipitation for Pebble 1, for the period 1942-2017 (i.e. for the period of record at Iliamna Airport). Details of the procedures used to generate the long-term temperature and precipitation series are presented in the 2018 Hydrometeorology Report (in progress).

The locations of the Pebble meteorology stations are shown on Figure 2.1. The locations of Iliamna Airport and three other regional meteorology stations are shown on Figure 2.2. Records from the other three regional stations (Port Alsworth, King Salmon, and Intricate Bay) were used to infill gaps in the Iliamna Airport temperature and precipitation records. A regional regression model was developed and used to estimate missing values in the Iliamna Airport record, based on derived scaling relationships and the strength of correlation between stations.

2.2.3 LONG-TERM MONTHLY TEMPERATURES AND PRECIPITATION AT PEBBLE 1

The long-term mean monthly temperature and precipitation values for the Iliamna Airport are presented on Figure 2.3 and Figure 2.4, respectively, and with the corresponding synthetic values developed for Pebble 1.

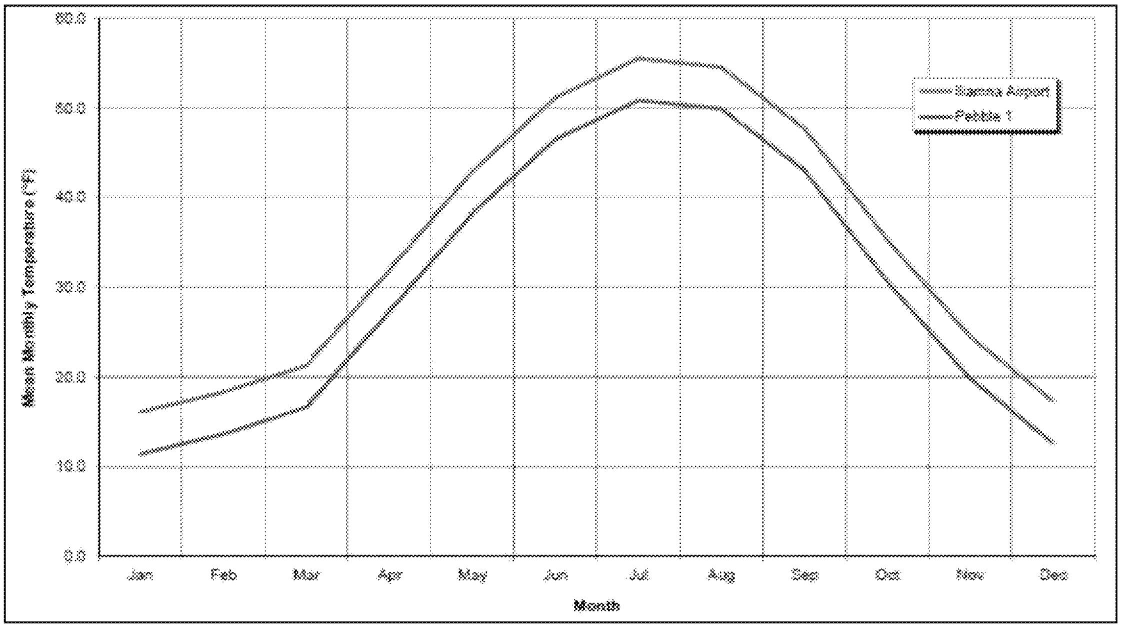


Figure 2.3 Mean Monthly Temperatures for Iliamna Airport and Pebble 1

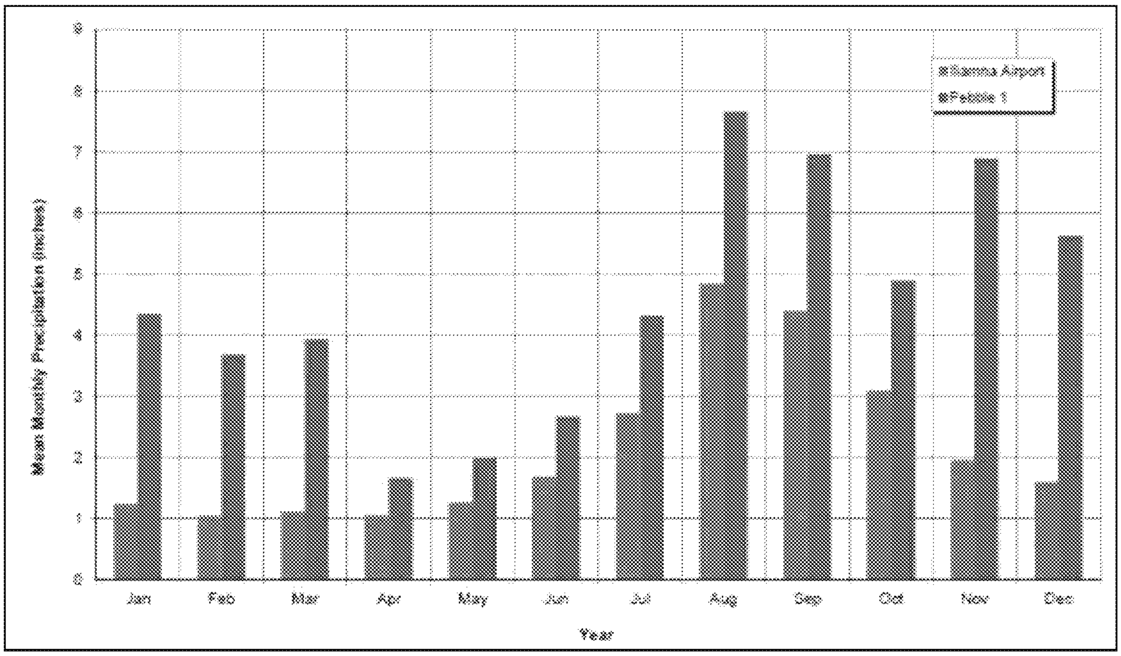


Figure 2.4 Mean Monthly Total Precipitation for Iliamna Airport and Pebble 1

The estimated long-term mean annual temperature at Pebble 1 is 30.1 °F, which is 4.7 °F colder than at Iliamna Airport (34.8 °F), as shown in Table 2.1. The coldest and warmest months at Pebble 1 are January and July, with estimated long-term mean monthly temperatures of 11.4°F and 50.8°F, respectively.

Table 2.1 Monthly and Annual Temperature Statistics for Pebble 1

	Monthly and Annual Mean Temperature (°F)			
Statistic	**Minimum**	**Mean**	**Maximum**	**St Dev**
Jan	-11.1	11.4	32.4	10.0
Feb	-3.5	13.6	31.4	8.7
Mar	-1.6	16.6	30.6	7.6
Apr	13.4	27.3	37.8	4.6
May	31.4	38.3	44.8	2.9
Jun	42.3	46.5	51.3	2.2
Jul	46.9	50.8	55.1	1.9
Aug	46.5	49.9	54.7	1.9
Sep	36.4	43.0	47.9	2.0
Oct	22.9	30.6	38.8	3.9
Nov	4.8	19.8	32.5	6.1
Dec	-11.2	12.6	30.7	8.9
Annual	23.6	30.1	37.1	2.7

NOTES:

1. STATISTICS OF A SYNTHETIC TEMPERATURE SERIES FOR THE PEBBLE 1 STATION LOCATION, ESTIMATED ON THE BASIS OF THE ILIAMNA AIRPORT RECORD (1942-2017), AS DESCRIBED IN MEMORANDUM VA18-00250 (KP 2018A).

The estimated long-term mean annual precipitation at Pebble 1 is 54.6 in., which is approximately two times greater than the mean annual precipitation recorded at Iliamna Airport (26.0 in.), as shown in Table 2.2. The wettest and driest seasons at Pebble 1 are late summer and early autumn (wettest) and spring (driest), with estimated long-term mean monthly precipitation values ranging from 7.7 in. in August to 1.7 in. in April.

Table 2.2 Monthly and Annual Precipitation Statistics for Pebble 1

	Monthly and Annual Mean Total Precipitation (in)				
Statistic	**Minimum**	**Mean**	**Maximum**	**St Dev**	**CV**
Jan	0	4.3	14.5	2.9	0.7
Feb	0	3.7	12.8	2.6	0.7
Mar	0	3.9	16.0	3.0	0.8
Apr	0.1	1.7	4.5	1.1	0.7
May	0	2.0	6.4	1.4	0.7
Jun	0	2.7	8.5	1.8	0.7
Jul	0.3	4.3	11.3	2.3	0.5
Aug	1.3	7.7	23.2	3.7	0.5
Sep	1.3	6.9	17.4	3.5	0.5
Oct	0.3	4.9	12.6	2.6	0.5
Nov	0	6.9	27.7	5.2	0.8
Dec	0.2	5.6	19.3	3.7	0.7
Annual	31.3	54.6	89.0	11.6	0.2

NOTES:
1. STATISTICS OF A SYNTHETIC PRECIPITATION SERIES FOR THE PEBBLE 1 STATION LOCATION, ESTIMATED ON THE BASIS OF THE ILIAMNA AIRPORT RECORD (1942-2017), AS DESCRIBED IN KP (2018A).

2.2.4 SPATIAL DISTRIBUTION OF TEMPERATURES AND PRECIPITATION

Monthly temperature and precipitation values were estimated for various locations throughout the Project area by adjusting the Pebble 1 values according to the following factors:

- Temperature was scaled using a lapse rate of -3.4 °F per 1,000 ft rise in elevation, and
- Precipitation was scaled using a combination of orographic and location factors that were derived from the calibration of the Pebble Project Watershed Module.

The orographic scaling factors for precipitation differ between winter months (defined as November through March) and non-winter months (defined as April through October), as described below:

- Winter: 34% increase per 1,000 ft rise in elevation, and
- Non-winter: 19% increase per 1,000 ft rise in elevation.

The different orographic factors reflect the differences between the meteorological conditions that prevail in winter and non-winter periods, as discussed in Section 2.2.1.

The location factors reflect other sources of spatial variability in precipitation and effective precipitation, including proximity to adjacent high-elevation terrain, windward/leeward effects, inter-basin snow drifting, and inter-basin groundwater flow.

The orographic and location scaling factors were estimated based on comparisons of streamflow station flow records, and then were adjusted as part of Watershed Module calibration to achieve a balance between meteorological inputs and corresponding groundwater and surface water values. The resulting spatial distribution of estimated long-term mean annual precipitation in the Project area is presented on Figure 2.2.

2.2.5 TEMPORAL VARIABILITY OF TEMPERATURE AND PRECIPITATION

The long-term synthetic series of annual precipitation for Pebble 1 is presented on Figure 2.5, and the cumulative departure of annual precipitation from the long-term mean is shown on Figure 2.6.

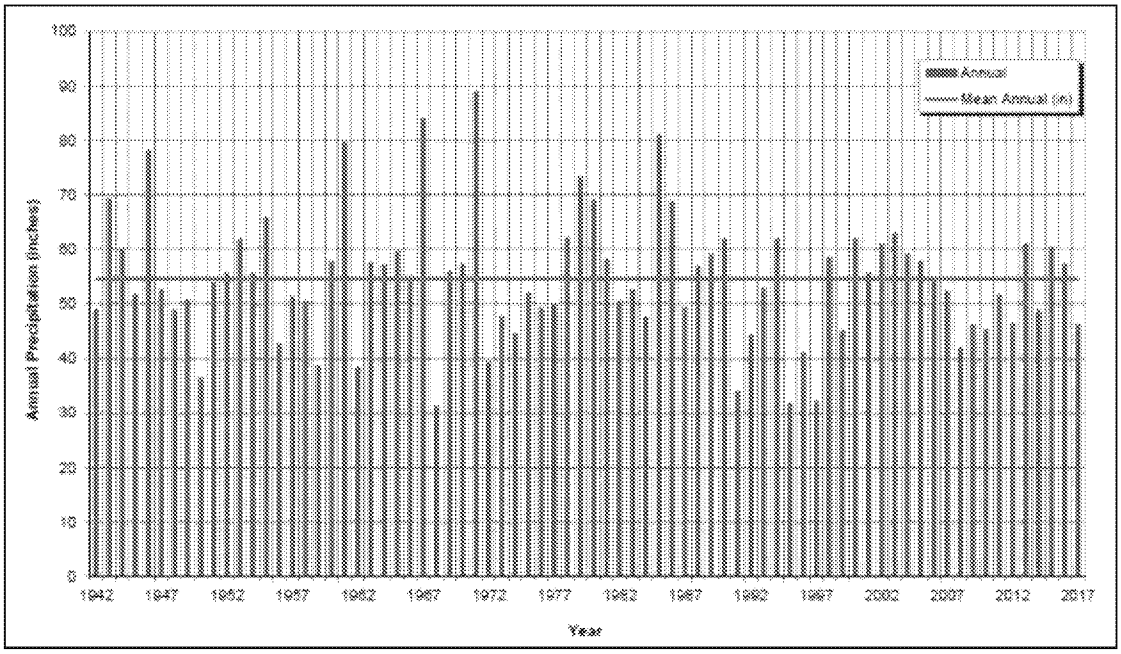


Figure 2.5 Annual Precipitation (estimated) for Pebble 1

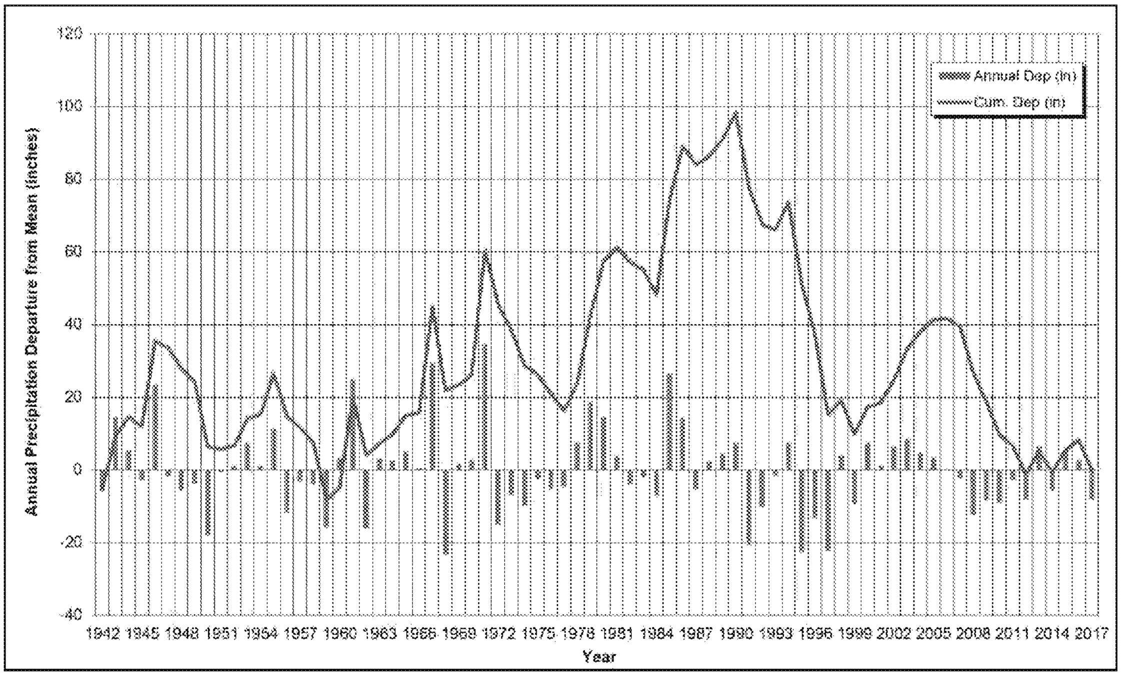


Figure 2.6 Annual Precipitation Departure from Mean Precipitation Conditions for Pebble 1

It is evident on Figure 2.6 that annual precipitation varies quite dramatically in the Project area, with many extended periods of wet and dry conditions. For instance:

- In the 1940s and 1950s, a few years of above average precipitation were followed by a few years of below average precipitation.
- From the 1960s onward, the cycles of high and then low precipitation were typically a little longer.
  - Annual precipitation was predominantly above average from 1960 to 1971, then predominantly below average from 1972-1977.
  - Annual precipitation was predominantly above average from 1978 to 1990, then predominantly below average from 1991 to 1999.
  - Annual precipitation was dominantly above average from 2000 to 2006, then dominantly below average from 2007 to 2012.
- Three of the four largest annual precipitation amounts occurred between the early 1960s and early 1970s; each of these years was followed by below-average precipitation the following year (i.e. dry years tend to occur even within decadal scale periods of dominantly above average annual precipitation).
- The greatest increase in cumulative departure of annual precipitation occurred between approximately 1978 and 1990 (i.e. this was the most pronounced period of predominantly above average precipitation).
- The greatest decrease in cumulative departure of annual precipitation occurred between 1991 and 1999 (i.e. this was the most pronounced period of predominantly below average precipitation).

2.2.6 EXTREME PRECIPITATION

Extreme precipitation intensity-duration-frequency curves were generated for the Pebble 1 station location and presented in the 2012 Hydrometeorology Report (KP, 2012). The IDF curves were generated according to the NOAA Atlas 14 Volume 7: Precipitation-Frequency Atlas of the United States, Alaska (NOAA, 2012), with adjustments for specific location and orographic effects. The IDF curves are based on annual extreme precipitation data, which includes both rainfall and snowfall.

2.3 SURFACE WATER HYDROLOGY CHARACTERISTICS

2.3.1 OVERVIEW

The Project straddles the headwater areas of the drainage basins of the North Fork Koktuli River (NFK), the South Fork Koktuli River (SFK), and Upper Talarik Creek (UTC), as shown on Figure 2.2.

The NFK and SFK join to form the Koktuli River mainstem approximately 17 miles west of the Project site. The Koktuli River flows into the Mulchatna River, which in turn flows into the Nushagak River. UTC flows into Iliamna Lake, which is drained by the Kvichak River. The NFK, SFK, and UTC drainage basins encompass a combined area of 347 square miles above the lowermost gaging station on each watercourse.

The study area topography is comprised of a series of hills interspersed with wide valleys infilled with glacial fluvial deposits, with elevations ranging from around 2,500 feet on hill peaks to 46 feet at Iliamna Lake. Weathered bedrock is exposed on upland surfaces, while thick sediment deposits are found in bedrock valleys (Hamilton and Klieforth, 2010). Glacial and fluvial sediments of varying thickness cover most of the Project area at elevations below about 1,400 feet and play an important role in surface water runoff and groundwater storage and exchange. Subsurface flows follow former pre-glacial surface drainage pathways in several areas that have since been buried by subsequent sediment deposits, resulting in some cross-basin transfers relative to the current surface topography.

2.3.2 STREAMFLOW GAGING STATIONS

Streamflow gaging stations were operated at 26 locations within the Project area for various periods between summer 2004 and autumn 2015. Three of the gaging stations were operated by the United States Geological Survey (USGS), and the remainder were operated by PLP. The station locations are shown on Figure 2.2. The USGS stations are NK100A, SK100B, and UT100B.

The three USGS gaging stations were operated from August 2004 until September 2015. Station SK100B was re-initiated in 2017. Flows at many PLP stations were found to be well correlated with flows at the USGS stations, allowing gaps in the PLP station records to be infilled using regression analysis. As a result, complete daily records of measured and synthesized flows could be developed for all stations for the period of 2004-2015. This period is referred to as the PLP streamflow gaging period.

The Pebble Project Watershed Module was used to generate long-term monthly streamflow values for each gaging station using climatic inputs from Iliamna Airport (KP 2018a). The streamflow series extend from 1942 to 2017, which is the period of record for the Iliamna Airport climate station.

2.3.3 STREAMFLOW RECORDS

The streamflow records collected in the Project area are summarized in Table 2.3, which presents mean annual discharge (cfs), mean annual unit discharge (cfs/mi²), and mean annual unit runoff depth (in./yr.) for each station. The table indicates a huge range of unit runoff values, from 16.8 in/yr at SK100C to 98.1 in/yr at UT119A, which reflects the substantial role that groundwater plays in the runoff at certain gages.

Table 2.3 Mean Seasonal Flow Distribution (2004 – 2015)

Drainage	Station	Drainage Area (mi²)	Mean Annual Discharge (cfs)	Mean Annual Unit Discharge (cfs/mi²)	Mean Annual Unit Runoff (in/yr)
South Fork Koktuli River	SK100A	106.92	254.5	2.38	32.3
	SK100B	69.33	179.6	2.59	35.2
	SK100B1	54.41	126.0	2.32	31.4
	SK100C	37.50	46.4	1.24	16.8
	SK100F	11.91	29.6	2.48	33.7
	SK100G	5.49	13.0	2.38	32.2
	SK119A	10.73	34.0	3.17	43.0
	SK124A	8.52	18.6	2.18	29.6
North Fork Koktuli River	NK100A	105.86	243.3	2.30	31.2
	NK100A1	85.34	201.2	2.36	32.0
	NK100B	37.32	82.6	2.21	30.0
	NK100C	24.35	46.7	1.92	26.0
	NK119A	7.76	23.7	3.05	41.4
	NK119B	3.97	4.2	1.06	14.4
Upper Talarik Creek	UT100-APC3	134.16	321.8	2.40	32.6
	UT100-APC2	110.16	292.9	2.66	36.1
	UT100-APC1	101.51	261.4	2.57	34.9
	UT100B	86.24	220.8	2.56	34.8
	UT100C	69.47	157.1	2.26	30.7
	UT100C1	60.37	121.1	2.01	27.2
	UT100C2	48.26	104.2	2.16	29.3
	UT100D	11.96	27.4	2.29	31.1
	UT100E	3.10	8.9	2.86	38.9
	UT106-APC1	14.14	43.2	3.05	41.5
	UT119A	4.05	29.3	7.22	98.1
	UT135A	20.42	44.7	2.19	29.7

Annual hydrographs of mean monthly discharge for the four gaging stations located closest to the mine site are presented on the following Figures 2.7 to 2.10. Hydrographs are presented for both the measured records (including gaps infilled using regression relationships) and for the long-term estimated streamflow series generated using the watershed module.

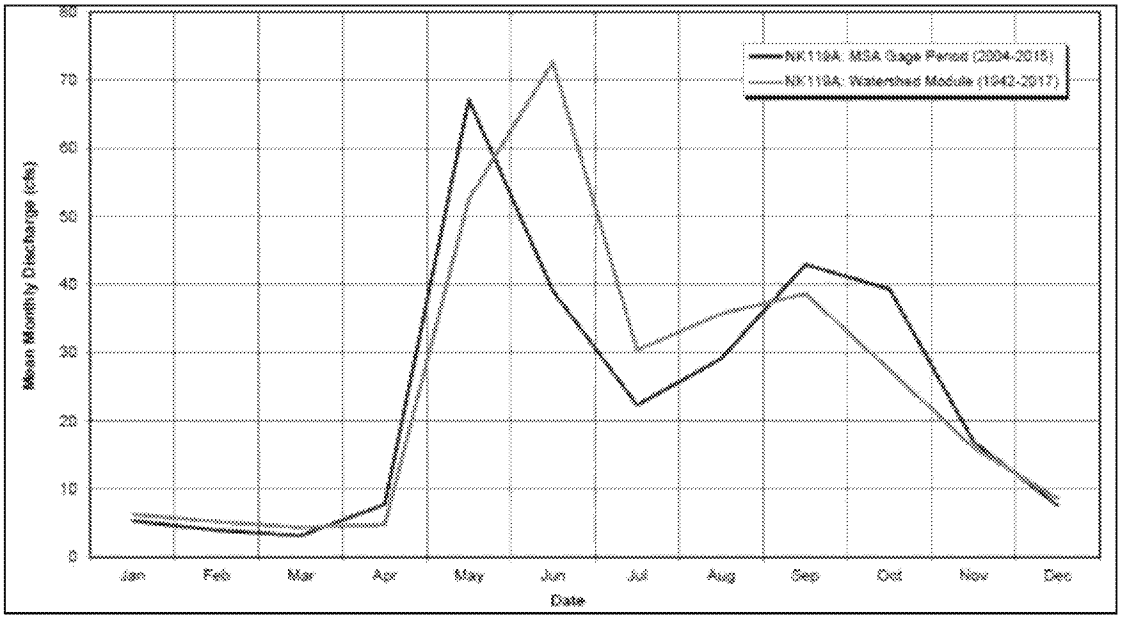


Figure 2.7 Mean Monthly Discharge for NK119A

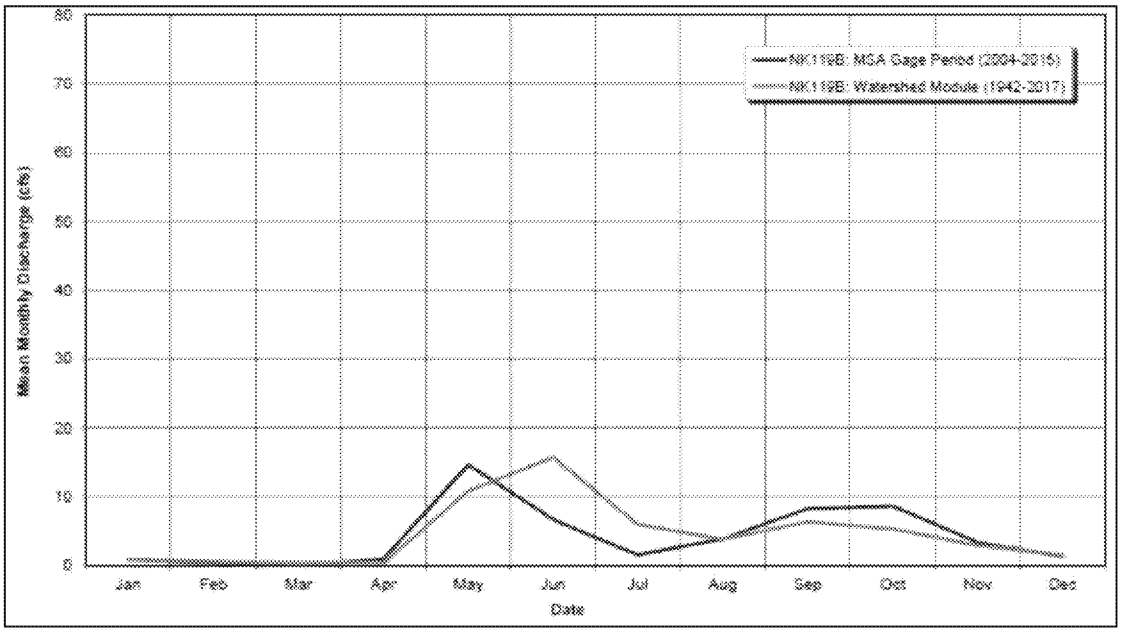


Figure 2.8 Mean Monthly Discharge for NK119B

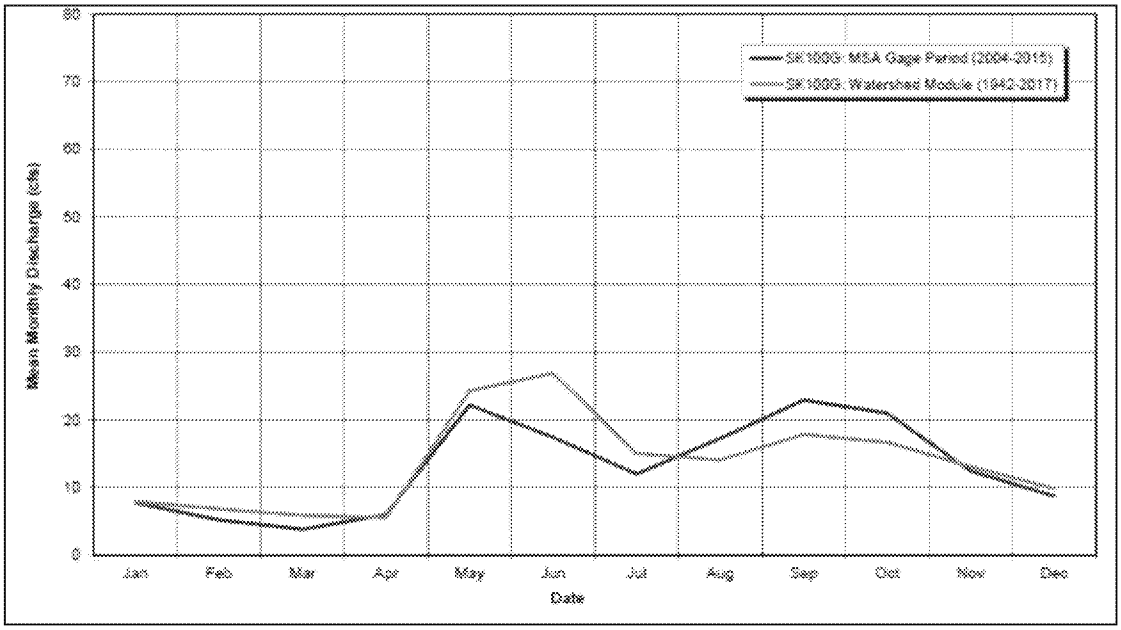


Figure 2.9 Mean Monthly Discharge for SK100G

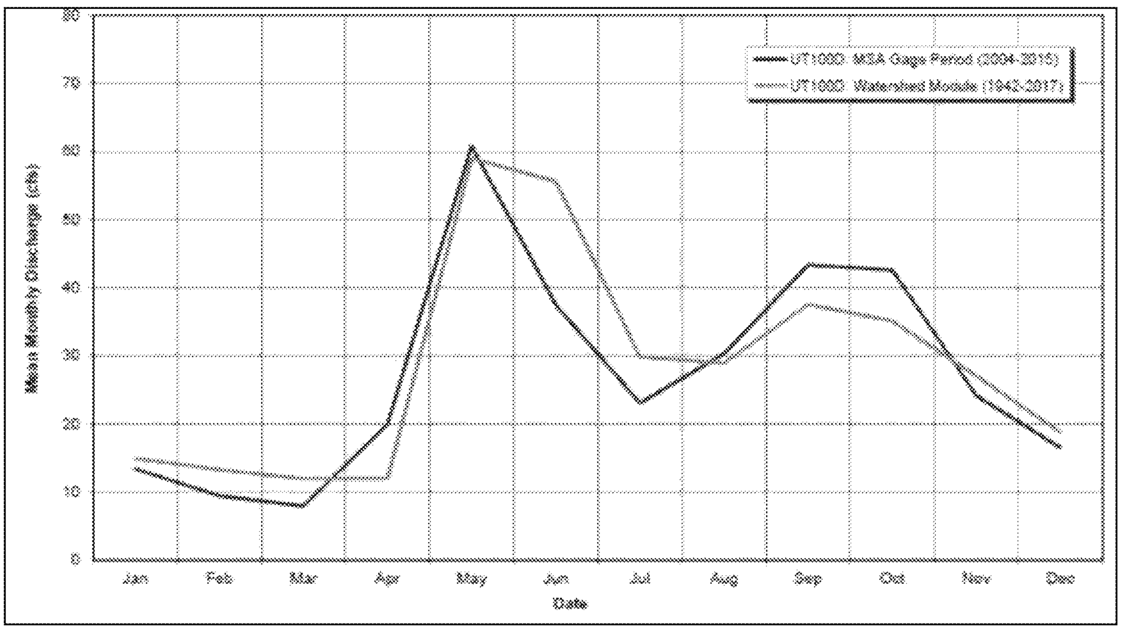


Figure 2.10 Mean Monthly Discharge for UT100D

To illustrate the year to year variability of flows in the Project area, daily discharge hydrographs for station NK119A are shown on Figure 2.11 for the driest year (2011), the wettest year (2013), and the average for the period of gage record.

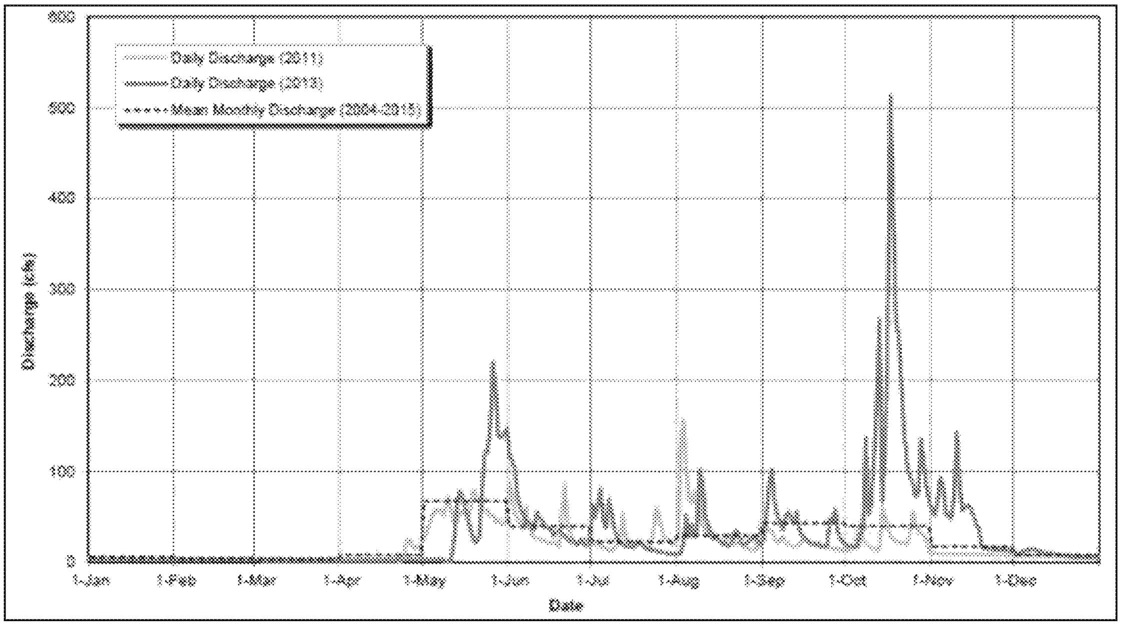


Figure 2.11 Daily Discharge Hydrographs for NK119A for Driest Year (2011) and Wettest Year (2013) on Record

2.3.4 SPATIAL AND TEMPORAL STREAMFLOW PATTERNS

The annual pattern of streamflows in the mine study area is characterized by:

- High flows in spring due to snowmelt
- Lower flows in early to mid-summer
- Another high-flow period in late summer and autumn due to frequent frontal rain storms, and
- Lowest flows in winter when most precipitation falls as snow and streams are fed almost exclusively by groundwater.

These seasonal patterns are apparent on the hydrograph figures presented above (Figure 2.7 through Figure 2.11) and in Table 2.4, which presents the distribution of streamflow by seasons for each gaging station.

At the lowermost gaging stations on the SFK, NFK, and UTC, the mean annual unit runoff was similar at all three stations, at around 2.3 to 2.4 cfs/mi^2. This equates to 31 to 33 in. of runoff depth at each station. The annual unit runoff for the other locations varied from gage to gage because of catchment topography and precipitation, cross-drainage transfers of groundwater, surface and subsurface flow exchanges along stream channels, and seasonal redistribution of snow by wind. In the upland tributaries gaged at NK119A and SK119A, the mean annual unit runoff values were 3.1 cfs/mi^2 and 3.2 cfs/mi^2, respectively, or 41 to 43 in. of runoff depth at each station. The higher unit runoff values at NK119A and SK119A, as compared to the lowermost gaging stations on the SFK, NFK, and UTC, are attributable mainly to catchment elevation and the orographic influence on precipitation.

Table 2.4 Mean Seasonal Flow Distribution (2004 – 2015)

Drainage	Station	Drainage Area (mi^2)	Mean Seasonal Flow Distribution (% of Annual Volume)					
			Primary Seasons (6 Months)		Non-Winter Seasons (2 Months)			Annual
			Winter (Nov-Apr)	Non-Winter (May-Oct)	Spring (May-Jun)	Summer (Jul-Aug)	Autumn (Sep-Oct)	
SFK	SK100A	106.9	27%	74%	29%	18%	26%	100%
	SK100B	69.3	22%	78%	32%	18%	29%	100%
	SK100B1	54.4	19%	81%	36%	17%	28%	100%
	SK100C	37.5	13%	87%	39%	16%	33%	100%
	SK100F	11.9	21%	80%	32%	19%	29%	100%
	SK100G	5.5	28%	73%	25%	19%	28%	100%
	SK119A	10.7	16%	84%	36%	19%	30%	100%
	SK124A	8.5	12%	89%	42%	16%	30%	100%
NFK	NK100A	105.9	22%	78%	35%	17%	26%	100%
	NK100A1	85.3	21%	80%	35%	18%	27%	100%
	NK100B	37.3	22%	78%	34%	17%	27%	100%
	NK100C	24.4	26%	74%	31%	16%	27%	100%
	NK119A	7.8	16%	85%	38%	18%	29%	100%
	NK119B	4.0	14%	87%	42%	11%	33%	100%
UT	UT100-APC3	134.2	34%	66%	24%	17%	25%	100%
	UT100-APC2	110.2	32%	68%	25%	16%	27%	100%
	UT100-APC1	101.5	33%	67%	24%	17%	26%	100%
	UT100B	86.2	34%	67%	26%	16%	25%	100%
	UT100C	69.5	33%	67%	26%	16%	26%	100%
	UT100C1	60.4	32%	69%	27%	15%	27%	100%
	UT100C2	48.3	28%	72%	30%	15%	27%	100%
	UT100D	12.0	28%	73%	30%	17%	26%	100%
	UT100E	3.1	34%	66%	27%	16%	24%	100%
	UT106-APC1	14.1	35%	65%	22%	18%	25%	100%
	UT119A	4.1	47%	53%	18%	17%	18%	100%
	UT135A	20.4	43%	58%	22%	12%	23%	100%
Average			27%	74%	30%	17%	27%	100%

2.3.5 PEAK FLOWS

Peak flow curves were generated for mainstem river channels and upland tributaries in the mine study area and presented in the 2012 Hydrometeorology Report (KP, 2012). The peak flow curves were generated based on streamflow gaging records available at that time, combined with regional regression equations generated by the USGS, in accordance with USGS peak flow estimation procedures specified by Curran et al (2003).

2.4 GROUNDWATER CHARACTERISTICS

Baseline groundwater hydrology and groundwater quality studies for the Project area were undertaken between 2004 and 2013. Data for parameters that are subject to seasonal variation, such as water levels and water quality, were collected year round. Data for other parameters that are independent of the seasons, such as aquifer properties, were collected between May and October of each year.

The study included the following elements:

- Collection of surface and subsurface geologic data.
- Examination of drilling logs including an assessment of the consistency to interpreted groundwater conditions.
- Installation of monitoring wells and standpipe piezometers, including multi-level well completions.
- Installation and testing of pumping wells.
- Measurement of hydrogeological parameters such as water levels and hydraulic conductivity
- Characterization of the flow and water quality of seeps.
- Delineation of groundwater recharge and discharge zones.
- Evaluation of sub-basin drainage areas, channel lengths, annual precipitation, topographic relief, flow regimes and stream characteristics.
- Characterization of groundwater quality in the overburden and bedrock groundwater systems.

Details and results of the groundwater hydrology and groundwater quality studies are presented in the 2015 Groundwater SEBD Chapter 8 (Groundwater Hydrology) and SEBD Chapter 9 (Water Quality) reports (PLP 2015a; 2015b). The groundwater conditions as described in PLP (2015a; 2015b) are summarized below.

Bedrock in the study area includes Jurassic and Cretaceous sedimentary and volcanic rocks, intruded by Cretaceous granodiorite to monzonite, and overlain by Tertiary sedimentary and volcanic rocks. Below the upper bedrock zone (upper 50 feet), the hydraulic conductivity generally decreases with depth but includes some elevated-permeability zones that are typically associated with faults. The available data suggest that many of the faults act as flow barriers perpendicular to their strike, while some of the structures demonstrate an enhanced permeability in the direction of strike. The pattern of faulting has resulted in the formation of groundwater compartments in bedrock at depth.

The upper slopes and ridges of the study area include exposures of highly fractured bedrock, talus, rubble, and solifluction deposits. The highly fractured bedrock provides a pathway for elevated rates of groundwater recharge beneath the bedrock ridges. High rates of water return during air-rotary drilling indicate that the hydraulic conductivity is usually relatively high in the upper bedrock due to weathering and frost disturbance. The weathered and disturbed zone is typically up to about 50-ft thick.

The lower slopes and valley bottoms are infilled primarily with glacial deposits, with some over-riding alluvial deposits. Several glacial periods have resulted in glacial advances and retreats within the study area. The glacial deposits in the study area were mostly formed during the Kvichak Stade of the Wisconsin Brooks Lake Glaciation and include end, lateral, and recessional moraines, ground moraines, outwash sands and gravels, and glacio-lacustrine deposits. Outwash sands and gravels are typically observed to have the highest hydraulic conductivity. The disturbed and weathered bedrock, up to 50-ft thick, has been documented under the lower slopes and valley bottoms throughout the Project area. The evidence includes intense fracturing observed in drill core, water return during air rotary drilling and hydrogeological testing.

Three permeable and extensive glacial sand and gravel deposits are of particular note in the valley fill sequence. These are:

- Along the SFK River south of Frying Pan Lake ("South Fork Koktuli Flats"). These deposits include a sand and gravel moraine, and sand and gravel outwash deposits.
- In the NFK River Valley downstream of the Kvichak Stade terminal moraines.
- East of UT Creek where there is extensive outwash and glacial contact sand and gravels.

Extensive low-permeability lacustrine deposits underlie the glacial Frying Pan Lake basin. Consistent with this low permeability, the lacustrine deposits are overlain by marshes. Similar low-permeability lacustrine deposits are present within the NFK River and UT Creek drainages.

The groundwater flow system in the study area is generally characterized as follows:

- Most groundwater flow in the study area occurs along local and/or intermediate flow paths. There is limited regional groundwater flow to the surrounding lowlands.
- The overall groundwater flow pattern across the study area is dominated by flow in approximately the upper 50-ft of the bedrock from the margins of the valley towards the valley floor, and groundwater underflow in a downstream direction along the axis of the valley, predominantly within permeable gravels where present and in the disturbed bedrock where overburden is dominated by fine grained deposits.
- Except for some cross-catchment flow between SFK River and UT Creek, the current assessment indicates that the majority of water that recharges the groundwater system within each of the three main drainages discharges within that drainage.
- To varying degrees, continuous permeable overburden units fill the bedrock valleys along each of the three main drainages. In most of the valley reaches, the majority of groundwater flow occurs within the overburden deposits. Groundwater underflow down the valley is much less where lower permeability deposits (silts and clays) are predominate in the alluvium. In these areas, the groundwater system tends to discharge to surface water, leading to gaining streamflow reaches. Conversely, where the alluvial deposits become more permeable downstream, or where the profile of the valley widens, the surface water system tends to infiltrate to groundwater, leading to losing stream reaches. The main reaches of streamflow losses and gains were characterized as part of the baseline study.
- The upper reaches of tributaries tend to have limited groundwater storage capacity, and therefore streamflows in the upper reaches are typically flashy, and late winter baseflows are relatively low.

- Further downstream, the sustained winter baseflows for the main stems in most parts of the Project area indicate considerable groundwater is contained in storage within the main part of the valleys. Baseflows are mostly higher where a substantial thickness of permeable alluvium is present upstream. The overall nature of the baseflow patterns tends to indicate that most of the groundwater storage on site occurs within the alluvium, and that most bedrock units demonstrate limited groundwater storage potential.
- Within each of the drainages, the surficial geology varies from low-permeability glaciolacustrine deposits to high-permeability glacial outwash and ice-contact deposits. The large differences in the permeability, coupled with variations in the topographic gradient, results in variability in the estimated localized recharge rates within each drainage.

The groundwater quality within the mine study area was assessed based on the collection of samples from 80 groundwater monitoring wells with depths up to about 200-ft and samples collected at drillhole DH-8417 at depths from 640 to 4,050-ft. The results of the groundwater sampling were compared to the most stringent criteria as defined in the Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substance by The Alaska Department of Environmental Conservation and Effluent Limitation Guidelines by the EPA. A summary from the water quality assessment by PLP (2015b) is below.

- Median total dissolved solids (TDS) of less than 80 mg/L for 60% of the wells, 80 to 300 mg/L for 35% of the wells and 400 to 500 mg/L for 5% of the wells.
- Median pH ranged between 5.8 and 9.6 in 79 out of 80 wells.
- Dissolved oxygen greater than 8 mg/L in 50% of the wells and less than 1 mg/L in 25% of the wells.
- Trace element concentrations were within water quality criteria in most cases and most wells with concentrations exceeding the respective criterion were located in proximity to the general deposit area.
- The groundwater was divided into three general classes based on TDS: high TDS close to the general deposit area, intermediate TDS at intermediate distances from the general deposit area, and low TDS at greater distances from the general deposit area.
- The wells with the highest proportion of sulfate were typically located closest to the general deposit area, suggesting the groundwater in this area is influenced by sulfide oxidation, which is typical near copper sulfide deposits.
- Trace element concentrations were generally higher in bedrock than in overburden. Seasonal variations in major ion concentration were observed in 16 wells, most of which were completed at more shallow depths.
- The TDS of deep groundwater samples collected from drillhole DH-8417 at depth intervals ranging from 640 to 4,050 feet increased with depth. Most of the samples collected at greater depths were of type sodium-calcium-sulfate and reached a TDS of 2,000 mg/L. The concentrations of some constituents in the overburden and shallow bedrock ground water wells were similar to the concentrations of the deep bedrock groundwater samples.

3.0 OPERATIONS WATER MANAGEMENT PLAN

3.1 GENERAL

Groundwater and surface water runoff within the Project mine site footprint has been characterized into the following groups:

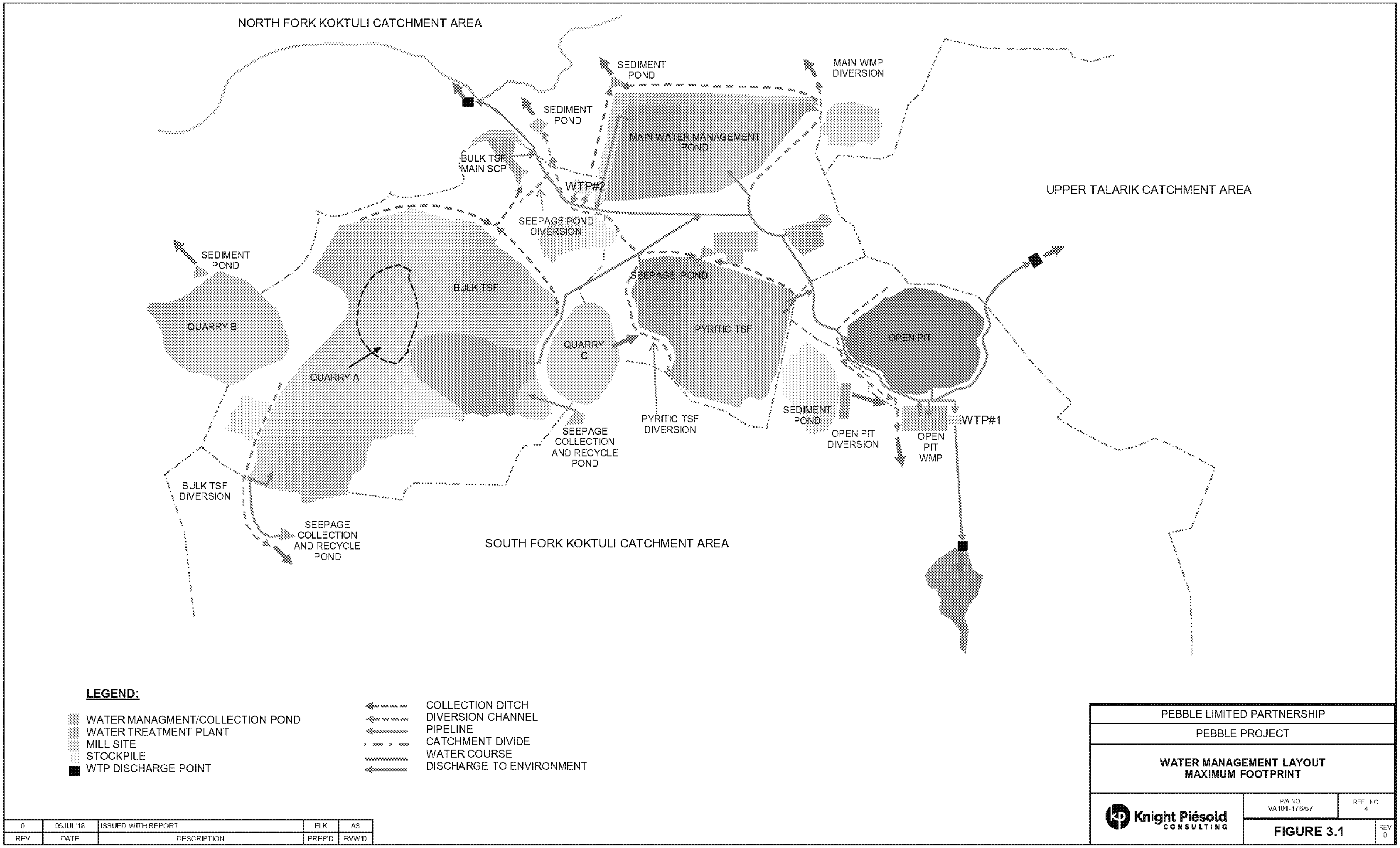
- Fresh water: water that has not come into direct contact with mining infrastructure and may be discharged to the environment without treatment in the water treatment plants (WTPs).
- Stormwater: runoff from facilities that does not come into direct contact with mining infrastructure, or is otherwise not classified as mine drainage, and therefore only requires treatment for sediment to meet discharge water quality standards prior to discharge to the environment. Stormwater is defined in 40 CFR 122.26 (b) (13) as "Stormwater runoff, snow melt runoff, and surface runoff and drainage". Stormwater will be discharged under general APDES Stormwater Permits.
- Mine drainage: groundwater or surface runoff that has come into direct contact with mining infrastructure and requires treatment at the water treatment plants to meet discharge water quality standards prior to discharge to the environment.
- Process water: wastewater generated from the Process Plant operations. Process wastewater is defined in 40 CFR 122.2 as "any water which during manufacturing or processing, comes into direct contact with or results from the production or use of any raw material, intermediate product, finished product, by-product, or waste product." Process wastewater will include water in the tailings slurry that is discharged to the Bulk TSF and the Pyritic TSF.

A simplified operational water management plan layout, which includes the main water management facilities, is shown on Figure 3.1. The management plan for fresh water, stormwater, mine drainage water, and process water is described in the sections below.

3.2 FRESH WATER AND STORMWATER MANAGEMENT

Diversion channels will direct fresh water around the mining infrastructure, where possible, and directly discharge it to the downstream environment. This will reduce the amount of water collected within the mine site footprint.

Stormwater runoff from the overburden stockpiles, the growth medium stockpiles, the quarries, and the downstream slopes of the OP WMP embankment, the Bulk TSF Main SCP embankment, and the Main WMP embankment, is assumed to not be contaminated and will be collected and treated locally at sediment ponds prior to release to the environment. Quarry A is located within the Bulk TSF impoundment area and will primarily be active during the initial construction of the Bulk TSF. Runoff from Quarry A during the early operations phase of the Project, prior to the quarry being submerged by the bulk tailings, will be collected and managed as part of the Bulk TSF supernatant pond. Surface runoff from Quarry B and Quarry C will be collected and treated within sediment ponds prior to release to the downstream environment. Quarry B will drain to a sediment pond that will discharge runoff towards the NFK, while Quarry C will drain to a pond that will discharge to the Pyritic TSF diversion channel, which in turn discharges to the NFK.



NORTH FORK KOKTULI CATCHMENT AREA
SEDIMENT POND
MAIN WMP DIVERSION
SEDIMENT POND
MAIN WATER MANAGEMENT POND
BULK TSF MAIN SCP
WTP#2
UPPER TALARIK CATCHMENT AREA
SEEPAGE POND DIVERSION
SEDIMENT POND
BULK TSF
SEEPAGE POND
QUARRY B
PYRITIC TSF
OPEN PIT
QUARRY C
QUARRY A
SEDIMENT POND
WTP#1
PYRITIC TSF DIVERSION
SEEPAGE COLLECTION AND RECYCLE POND
OPEN PIT DIVERSION
OPEN PIT WMP
BULK TSF DIVERSION
SEEPAGE COLLECTION AND RECYCLE POND
SOUTH FORK KOKTULI CATCHMENT AREA
LEGEND:
WATER MANAGMENT/COLLECTION POND
WATER TREATMENT PLANT
MILL SITE
STOCKPILE
WTP DISCHARGE POINT
COLLECTION DITCH
DIVERSION CHANNEL
PIPELINE
CATCHMENT DIVIDE
WATER COURSE
DISCHARGE TO ENVIRONMENT
0 05JUL'18 ISSUED WITH REPORT ELK AS
REV DATE DESCRIPTION PREP'D RVW'D
PEBBLE LIMITED PARTNERSHIP
PEBBLE PROJECT
WATER MANAGEMENT LAYOUT
MAXIMUM FOOTPRINT
Knight Piésold CONSULTING
P/A NO. VA101-176/57
REF. NO. 4
FIGURE 3.1
REV 0

3.3 MINE DRAINAGE AND PROCESS WATER MANAGEMENT

The mine drainage and process water management strategy for the various water sources is presented in this section. Mine drainage and process water from around the Project site will be collected and managed using various water management facilities, which are further described in Section 3.4.

Groundwater and surface runoff collected in the Open Pit and surrounding area will be directed to the OP WMP, prior to being treated at WTP#1. Treated water from WTP#1 will be released to the environment downstream of the Project mine site.

Mine drainage water and process water from outside of the Open Pit and surrounding area, including surface runoff from the process plant site and power plant site, TSF seepage water, and surplus supernatant water on the TSFs, will be directed to the Main WMP.

The Main WMP will provide surge capacity for runoff from the mine site. Surplus mine drainage and process water from the TSFs, seepage, groundwater, and runoff from the Bulk TSF Main SCP and the seepage pond at the north end of the Pyritic TSF, will be pumped to the Main WMP to minimize the volume of water stored within these facilities. The operating capacity of the Main WMP was sized to manage surplus water from the mine site and to supply water to the process over the full range of historic climate conditions.

Surplus water from the Main WMP will be treated at WTP#2. A small portion of the treated water will be used to satisfy the clean water requirements for the process and power plant, while the remainder will be discharged downstream of the mine site. No fresh water from outside of the mine site footprint will be used to satisfy the processing requirements.

The capacities of the water treatment plants were determined by balancing the storage capacity and the water management ponds with the water treatment rates to provide a reliable source of process water during dry climate conditions and the ability to manage surplus water during wet climate conditions. The maximum treatment capacity of WTP#1 was determined to be 14 cfs, and the maximum treatment capacity of WTP#2 was determined to be 38 cfs.

3.3.1 OPEN PIT DEWATERING

Dewatering of the Open Pit will be required to initiate and maintain mining activities. The development of the ultimate pit dewatering design will be based on a series of interim pit phases that reflect successive deepening and cutback of the pit. The interim pit phases will use perimeter and in-pit wells to collect groundwater. This phased approach will allow the ultimate pit dewatering approach to be based on the operational performance of each preceding phase. Mine dewatering and control of the pore pressures in the pit slopes are interrelated and will therefore be developed coincidently.

Groundwater collected from the Open Pit will be directed toward the OP WMP for temporary storage and then treatment prior to discharge to the environment downstream of the Project mine site. Runoff from areas upslope of active mining areas will be intercepted and diverted around the Open Pit perimeter where possible. Runoff and snowmelt from the Open Pit walls will be collected and pumped using in-pit pumps to the OP WMP for storage and treatment prior to discharge to the environment downstream of the Project mine site. The pumping capacity of the dewatering system will be designed to keep active mining areas dry during normal operating conditions, with contingency measures in place to handle periods with higher flow.

3.4 WATER MANAGEMENT FACILITIES

The following sections describe the major water management facilities proposed to execute the water management plan for the Project. The design criteria for the water management structures are outlined in Table 3.1. The maximum operating pond volume and minimum operating pond volume (where applicable) were determined with the climate variable water balance.

Table 3.1 Design Criteria Table for the Water Management Structures

Water Management Structure	Design Criteria
Fresh Water Diversion Channels	Convey undisturbed surface water runoff around the mine site facilities to the downstream environment.
OP WMP	Maximum operating pond volume of 40 Mft^3 (920 ac-ft) to manage dewatering from the Open Pit. Water in excess of this capacity will be pumped to the Main WMP for management. Storm storage freeboard allowance for the required IDF and a spillway to safely pass larger events with additional freeboard[1]
Main WMP	Minimum operating pond volume of 300 Mft^3 (6,900 ac-ft) to ensure that there is sufficient water available for the process during dry climate conditions. Maximum operating pond volume of 2,450 Mft^3 (56,250 ac-ft) to manage surplus water from the Project mine site during wet climate conditions. Storm storage freeboard allowance for the required IDF with additional freeboard[1]
Bulk TSF	Maximum operating pond volume varies by embankment stage and mine development, but is constrained by the need to maintain a minimum 2,000 ft beach length. Storm storage freeboard allowance for the required IDF without release from the facility with additional freeboard[1]
Bulk TSF Main SCP	Maximum operating pond volume of 130 Mft^3 (3,000 ac-ft) to manage seepage and runoff from the main embankment of the Bulk TSF. Storm storage freeboard allowance for the IDF and a spillway to safely pass larger events with additional freeboard[1]
Pyritic TSF	Minimum operating pond volume varies by embankment stage and mine development, but is constrained by the requirement to maintain a water cover to promote geochemical stability of the pyritic tailings and PAG waste rock. Storm storage freeboard allowance for the required IDF and a spillway to safely pass larger events with additional freeboard[1]
Seepage Collection and Recycle Ponds	Ponds are to be operated with the minimum pond volume required by the pump systems. Storm storage freeboard allowance for the required IDF and a spillway to safely pass larger events with additional freeboard[1]
Sediment Ponds	Treat sediment for all inflows resulting from the 1 in 10-year, 24-hour rainfall event, with no flow passing over the spillway. Spillway to safely pass the peak outflows resulting from the 1 in 200-year, 24-hour rainfall event, with the starting pond level at the spillway invert. Additional freeboard provided.[1]

NOTES:
1. EACH WATER MANAGEMENT POND WILL INCLUDE AN ADDITIONAL FREEBOARD ALLOWANCE FOR WIND-GENERATED WAVE HEIGHT AND POTENTIAL SEISMIC DEFORMATION.
2. IDF: INFLOW DESIGN FLOOD.
3. THE REQUIRED IDF FOR EACH WATER MANAGEMENT POND WILL BE DETERMINED THROUGH THE ALASKA DAM SAFETY PROGRAM (ADSP).

3.4.1 FRESH WATER DIVERSION CHANNELS

Fresh water diversion channels are proposed to collect and convey surface water runoff from undisturbed ground and directly discharge it to downstream waterways. The channels will be sized to convey the specified design storm and will be constructed at a gradient to promote free-drainage and minimize ponding. The channels will be lined where required to minimize the potential for erosion and sediment entrainment. The assumed efficiency of the channels is 50% for channels situated at elevations above 1,400 fasl, and 80% for channels situation at elevations below 1,400 fasl. The proposed fresh water diversion channels are shown on Figure 3.1 and include the following:

- An Open Pit diversion channel to divert undisturbed runoff from areas north and west of the Open Pit southward to the SFK.
- A Pyritic TSF diversion channel to divert undisturbed runoff from areas west of the Pyritc TSF northward to the NFK.
- A Bulk TSF diversion channel to divert undisturbed runoff from areas southwest of the Bulk TSF southward to the SFK.
- A Bulk TSF Main SCP diversion channel to divert undisturbed runoff from areas east of the Bulk TSF Main SCP northward to the NFK.
- A Main WMP diversion channel to divert undisturbed runoff from areas east of the Main WMP northward to the NFK.

Flows collected in the fresh water diversion channels will be conveyed directly to the downstream waterways. These flows are expected to follow a similar pattern to the pre-mine hydrograph, with high flows occurring during the spring snowmelt season and fall rainy season, and low flows occurring during the late summer period. Minimal flows are expected during the winter when precipitation will mostly fall as snow.

3.4.2 OPEN PIT WATER MANAGEMENT POND

The OP WMP will be a lined facility. The maximum operating pond volume and freeboard criteria for the OP WMP are outlined in Table 3.1. The storm storage freeboard allowance will be provided in addition to the maximum operating pond volume, and the emergency spillway will be set at an elevation above the IDF freeboard and will direct flows towards the SFK. Water in excess of the maximum operating pond volume will be directed to the Main WMP. Collection ditches along the toe of the embankments will direct stormwater runoff to a sediment control pond for treatment prior to release to downstream waterways. Water collected within the OP WMP will be treated for discharge at WTP#1.

3.4.3 MAIN WATER MANAGEMENT POND

The Main WMP will provide water storage surge capacity for the mine site and is a key component of the water management strategy. Water collected in all of the other water management ponds, excluding the OP WMP, will be directed to the Main WMP to minimize the storage requirements of these ponds. The Main WMP will be a lined facility, with underdrains installed below the liner to direct groundwater drainage under the facility and towards the sediment control pond. Collection ditches along the toe of the embankments will direct stormwater runoff from the embankments to a sediment control pond for treatment prior to release to the downstream environment.

The operating capacity of the Main WMP was sized using the climate variability water balance model, for purposes of safely managing the surplus water from the mine site and supplying water to the process under the full range of climate conditions. The minimum and maximum pond volumes and freeboard criteria for the Main WMP are outlined in Table 3.1.

Excess water accumulation within the pond that would infringe upon the storm storage requirements, and which is not a result of the IDF inflow, will be directed to the Open Pit for temporary storage. The Main WMP will include an emergency spillway designed to safely convey the peak discharge from the IDF, and will direct flows to the NFK.

3.4.4 BULK TAILINGS STORAGE FACILITY

The Bulk TSF will be used to manage bulk tailings solids and supernatant water prior to pumping surplus water to the Main WMP. The Bulk TSF will provide sufficient storage capacity for the tailings, the operating pond, and a freeboard allowance as outlined in Table 3.1, without release to the downstream environment. The water management strategy for the Bulk TSF is to maintain a minimum supernatant pond with maximum beaches by pumping surplus water to the Main WMP via the reclaim water pumping system.

The main embankment of the Bulk TSF is proposed to operate as a drained facility to promote long-term drainage of the bulk tailings mass. The Bulk TSF Main SCP, located downstream of the main embankment of the Bulk TSF, will collect seepage that drains through the main embankment. Water collected in the Bulk TSF Main SCP will be pumped to the Main WMP. The Bulk TSF south embankment is proposed to include a hydraulic barrier, consisting of a HDPE liner or a low permeability core zone, and a grout curtain installed in the weathered bedrock. A seepage collection pond will be located downstream of the south embankment to collect any potential seepage and embankment runoff. A seepage collection pond will also be constructed on the east side of the Bulk TSF to collect potential seepage and runoff from the east side of the facility. Water collected in the south and east seepage collection ponds will be pumped back into the Bulk TSF.

3.4.5 BULK TSF MAIN EMBANKMENT SEEPAGE COLLECTION POND

The Bulk TSF Main SCP is the main seepage collection system for the Bulk TSF and will be used to manage seepage and runoff flows from Bulk TSF main embankment. Water collected in the Bulk TSF Main SCP will be pumped to the Main WMP. The maximum operating pond volume, storm storage, freeboard, and spillway criteria for the seepage pond are outlined in Table 3.1. Collection ditches along the toe of the Bulk TSF Main SCP embankment will direct stormwater runoff to a sediment control pond for treatment prior to release to the downstream environment.

An emergency spillway will be set at an elevation above the IDF freeboard and will direct discharges towards the NFK.

3.4.6 PYRITIC TAILINGS AND PAG WASTE ROCK STORAGE FACILITY

The Pyritic TSF will manage pyritic tailings solids, PAG waste rock and supernatant water. The Pyritic TSF will be lined and is a water retaining facility, and will provide sufficient storage capacity for the tailings, PAG waste rock, operating pond, and freeboard allowance as outlined in Table 3.1. The water management strategy for the Pyritic TSF is to maintain a water cover over the surface of the tailings and waste rock to maintain geochemical stability. Surplus water will be directed to the Main WMP via the reclaim water pumping system.

The Pyritic TSF will contain the IDF without release to the downstream environment, and an emergency spillway will be included in the design.

Underdrains will be included below the facility to direct groundwater and seepage to a collection pond downstream of the main Pyritic TSF embankment. The seepage collection pond will also collect stormwater from the main embankment. Water collected in the seepage collection pond will be pumped to the Main WMP. Additional seepage collection and recycle ponds will be constructed around the Pyritic TSF. Flows collected within these facilities will be recycled back into the Pyritic TSF.

3.4.7 SEEPAGE COLLECTION AND RECYCLE PONDS

Seepage collection and recycle ponds will be located downstream of the Bulk TSF south embankment, the Bulk TSF east side, and the Pyritic TSF south embankment.

The operating criteria, storm storage and spillway criteria for the seepage collection and recycle ponds are outlined in Table 3.1. Seepage flows will be pumped back to each respective TSF, as required.

3.4.8 SEDIMENT PONDS

Sediment ponds will be located downstream of various embankment structures throughout the mine site to collect and treat non-mine drainage stormwater from these facilities. Sediment ponds will be located downstream of the overburden stockpiles, growth medium stockpiles, the OP WMP, the Bulk TSF Main SCP, the Main WMP embankments, and the quarries. The operating criteria, storm storage, and spillway criteria for the sediment ponds are outlined in Table 3.1. Releases from the sediment ponds are expected to follow a similar pattern to the pre-mine hydrograph with high flows occurring during the spring snowmelt and fall rainy seasons, and low flows occurring during the late summer period. Minimal flows are expected during the winter when most of the precipitation will fall as snow.

3.4.9 WATER TREATMENT PLANTS

There are two water treatment plants proposed for the project to treat surplus water: WTP#1, which is located near the OP WMP, and WTP#2, which is located near the Main WMP. Variable water treatment rates were required to manage the surplus water from the mine site under the full range of historic climate conditions. Higher water treatment rates will be required during extended wet periods and reduced water treatment rates will be required during extended dry periods. The treatment rates for WTP#1 and WTP#2 are dictated by the volumes of water stored in the OP WMP and the Main WMP, respectively. Trigger volumes in the water management ponds correspond to treatment rates at the water treatment plants, as defined in Table 3.2 for WTP#1 and the OP WMP, and in Table 3.3 for WTP#2 and the Main MWP.

Table 3.2 WTP#1 Operational Strategy – Open Pit WMP Trigger Volumes and WTP#1 Rates

Case	Open Pit WMP Trigger Volume		WTP#1 Inflow Rate	Description
	(Mft^3)	(ac-ft)	(cfs)	
Low	< 4	< 90	4.7	1 train (33% of total treatment capacity)
Average	4 to 8	90 to 185	9.3	2 trains (66% of total treatment capacity)
High	> 8	> 185	14.0	3 trains (100% of total treatment capacity)

NOTES:
1. SOURCE FOR THE NUMBER OF WATER TREATMENT TRAINS IS HDR (2018A).

Table 3.3 WTP#2 Operational Strategy – Main WMP Trigger Volumes and WTP#2 Rates

Case	Main WMP Trigger Volume		WTP#2 Inflow Rate	Description
	(Mft^3)	(ac-ft)	(cfs)	
Low-Low	< 300	< 6,900	9.5	1 train (25% of total treatment capacity)
Low	300 to 1,200	6,900 to 27,500	19.0	2 trains (50% of total treatment capacity)
High	1,200 to 1,500	27,500 to 34,400	28.5	3 trains (75% of total treatment capacity)
Maximum	> 1,670	38,300	38.0	4 trains (100% of total treatment capacity)

NOTES:
1. SOURCE FOR THE NUMBER OF WATER TREATMENT TRAINS IS HDR (2018A).

The water treatment plants will produce reject sludge. The reject sludge flow rate is assumed to be 0.1% of the inflow rate to the water treatment plants (HDR 2018a). In addition, WTP#2 has an RO reject rate of 2.3% of the inflow rate to WTP#2 (HDR 2018a). The reject sludge and RO reject will be pumped to the mill and will be added to the pyritic tailings slurry pipeline to be disposed of within the Pyritic TSF.

Treated water from WTP#1 and WTP#2 that is not required at the process plant or the power plant will be discharged. Treated water discharge locations are proposed in the NFK, SFK and UT catchments, as shown on Figure 1.1.

4.0 OPERATIONS WATER BALANCE MODEL

4.1 INTRODUCTION

A water balance model for the operations period of the mine was developed for the Project. The water balance is comprised of three modules: the Watershed Module, the Groundwater Module, and the Mine Plan Module. This section describes the Mine Plan Module (the model) of the water balance and presents the associated inputs, assumptions, and results. The Mine Plan Module is representative of the movement of water within the mine system, and it uses inputs from the Watershed Module and the Groundwater Module. The Mine Plan Module estimates the amount of water to be managed at the mine site during the full operating period of the mine under a full range of historic climate conditions.

4.2 INPUTS AND ASSUMPTIONS

The Mine Plan Module was completed on a monthly basis using GoldSim® software, and was based on the conceptual 20-year life of mine footprint shown on Figure 1.1 and the water management strategy described within this report. The water management strategy incorporated into the Mine Plan Module is shown as a flow schematic on Figure A.1 in Appendix A. The model assumes a constant nominal milling rate of 180,000 tpd and that the maximum mine footprint is applicable to every year of operations.

Climate variability was incorporated into the model by utilizing the 76-year synthetic time-series of monthly temperature and precipitation values developed for the Project site. The time-series data were incrementally stepped by year within the model, for the planned life of the Project, thereby preserving the inherent cyclical nature of the climate record. The model generated 76 unique sets of results of water flow and storage for each month of each year of the model.

Additional inputs and assumptions for the model include:

- The ore, concentrate and tailings properties are as follows (Ausenco 2017a):
    - Ore has a 3% water content and a specific gravity (SG) of 2.6.
    - Concentrate is classified into two types:
        - Copper concentrate with an 8% water content and an SG of 3.1.
        - Molybdenum concentrate with a 12% water content and an SG of 3.2.
    - Bulk tailings has an SG of 2.6.
    - Pyritic tailings has an SG of 2.9.
- The bulk tailings dry density is assumed to be 90 pcf.
- The pyritic tailings dry density is assumed to be 100 pcf.
- The flow-through rate of the Bulk TSF main embankment is assumed to be a constant rate of 8 cfs during operations (KP 2018b).
- A total tonnage of approximately 126 million short tons of PAG waste rock is stored in the Pyritic TSF during operations (approximate volume of 500 million ft3 assuming a density of 120 pcf).

- Groundwater inflow to the Open Pit is at a constant rate of 2,700 gpm (6 cfs), as provided by Piteau Associates.
- Approximately 3 cfs of treated water from the water treatment plants is required at the mill for processing, (Ausenco 2017b).
- Approximately 3 cfs of treated water from the water treatment plants is required at the power plant cooling towers, and approximately 265 gpm (0.6 cfs) of blow-down water will be directed to the Main WMP (WorleyParsons 2017).
- Treated water to the mill and power plant is sourced from WTP#2.
- WTP#1, which is located near the Open Pit, has a maximum treatment rate of 14 cfs provided by three trains of equal treatment capacity (HDR 2018a). The reject sludge from WTP#1 is assumed to be directed to the Pyritic TSF through the pyritic tailings line.
- WTP#2, which is located near the mill, has a maximum treatment rate of 38 cfs, provided by four trains of equal treatment capacity (HDR 2018a). The reject sludge and reject flow from WTP#2 will be directed to the Pyritic TSF through the pyritic tailings line.

4.3 MINE PLAN MODULE WATER BALANCE RESULTS

4.3.1 ANNUAL AVERAGE BALANCE

The module schematic and corresponding average annual flows are shown on Figure A.1 and in Table A.1, in Appendix A. The values include the average annual inflows and outflows for the water management facilities for three unique model runs (realizations), which were selected from the entire set of 76 model realizations. These selections represent relatively dry, average, and relatively wet conditions, and illustrate the range of potential flows for the mine site. The realizations all have similar average precipitation values, but differ in how the precipitation varies from year to year. The realizations selected are:

- Realization #36 was selected to represent relatively dry conditions because it contains a period that results in low environmental discharge releases. The average annual precipitation for realization #36 is 56 in., but the annual precipitation in the final year of operations is 33 in.
- Realization #5 was selected to represent average conditions because it results in relatively constant environmental discharge releases. The average annual precipitation for realization #5 is 57 in. and the annual precipitation for the final year of operations is 58 in.
- Realization #10 was selected to represent relatively wet conditions because it contains a period that results in high environmental discharge releases. The average annual precipitation for realization #10 is 57 in., but the annual precipitation for the final year of operations is 93 in.

The volume of fresh water, stormwater, and mine drainage water that is managed within the Project mine site is a function of the climate. More water will be collected and managed during wet climate conditions compared to during dry climate conditions. The relatively wet condition (realization #10) in Table A.2 corresponds to more runoff and direct precipitation being collected within the water management facilities than the relatively dry condition (realization #36). The amount of process water managed during the three realizations is the same because this is a function of the processing throughput rate and the tailings properties (e.g. the throughput rate and percent solids in the tailings streams dictate the amount of water in the tailings slurries), and is independent of the climate conditions.

Water losses (or water that is not available for the process or for treatment and discharge) include evaporation from the surfaces of the water management ponds and the cooling towers of the Power Plant, water that is lost or trapped in the Bulk tailings voids stored in the Bulk TSF and the Pyritic tailings voids and PAG waste rock voids stored in the Pyritic TSF, and a small amount of water that leaves with the concentrate. The losses are independent of the climate conditions and are a function of the processing throughput rate, the tailings and waste rock properties, and the Power Plant design. The losses are therefore similar under all climatic conditions.

The amount of surplus water at the site is a function of the total amount of water entering the site and the total water losses. The amount of surplus water increases during wet climate conditions since the amount of inflow increases, but the amount of losses are the same as during dry climate conditions. The total site surplus water for the realizations selected to represent relatively dry, average, and relatively wet conditions are summarized in Table 4.1. The site surplus water for the Project will be stored within the water management ponds and then treated and released downstream of the mine site.

Table 4.1 Average Annual Site Wide Surplus Flow for Individual Realizations Representing Relatively Dry, Average, and Relatively Wet Conditions

		Average Annual Flows (cfs)		
		Relatively Dry Conditions (Realization #36)	**Average Conditions (Realization #5)**	**Relatively Wet Conditions (Realization #10)**
Inflows				
	Water in Ore	2	2	2
	Groundwater to Open Pit	6	6	6
	Mine Drainage	21	44	81
	Total Inflows	**29**	**52**	**89**
Losses				
	Concentrate	<1	<1	<1
	Tailings Voids	20	20	20
	Pond Evaporation	3	3	3
	Power Plant Evaporation	2	2	2
	Dust Control	<1	<1	<1
	Total Losses	**25**	**25**	**25**
Site Surplus (Inflows - Losses)		**4**	**27**	**64**

NOTES:

1. THE SURPLUS FLOW IS AN INDICATION OF THE AMOUNT OF WATER THAT IS COLLECTED AND MANAGED WITHIN THE PROJECT MINE SITE. THE SURPLUS FLOW IS NOT DIRECTLY RELATED TO THE AMOUNT OF WATER TREATED AND RELEASED DOWNSTREAM OF THE PROJECT SITE AT ANY ONE TIME SINCE THE SITE SURPLUS DOES NOT TAKE INTO ACCOUNT THE CHANGE IN WATER STORED WITHIN THE WATER MANAGEMENT PONDS.

4.3.2 MAIN WMP VOLUMES

Estimated pond volumes for the Main WMP, provided in terms of monthly 1st, 10th, 50th, 90th, and 99th percentile values, are shown on Figure 4.1. These results indicate that the Main WMP will operate below the maximum operating pond capacity at all times, and that there is sufficient water available in the pond to satisfy the process reclaim water requirements (the pond does not go dry), even during prolonged dry periods.

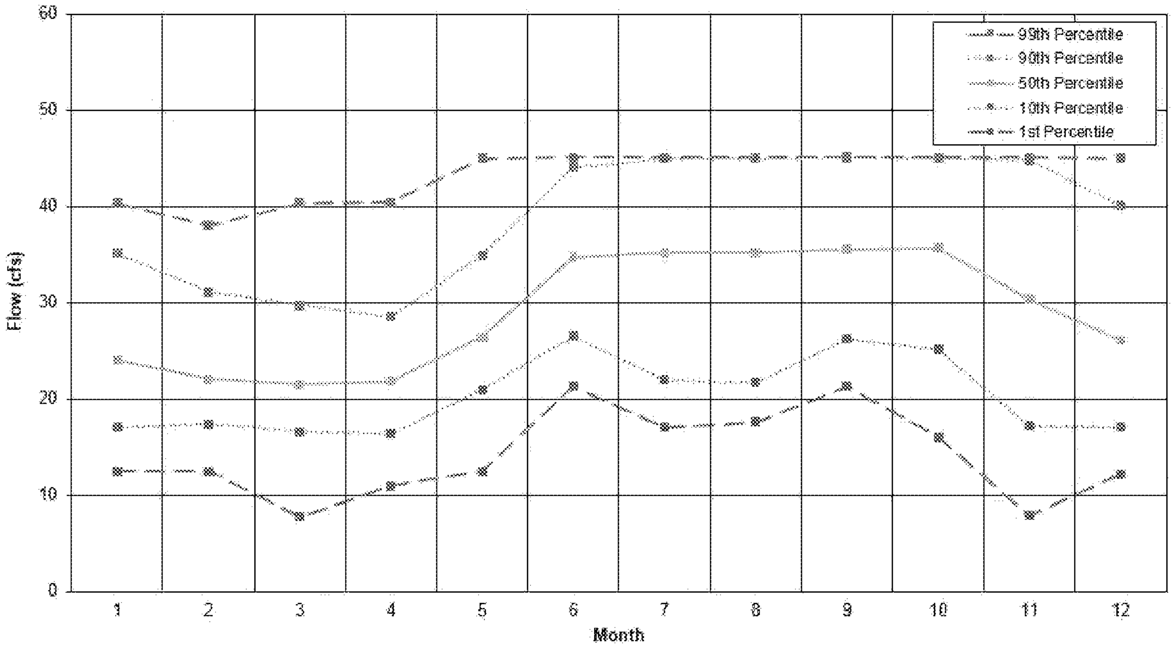


Figure 4.1 Main WMP Volumes Results and Operating Capacity – 1st, 10th, 50th, 90th, and 99th Percentiles

4.3.3 TOTAL RELEASE FROM THE WATER TREATMENT PLANTS

The total flows released downstream of the Project mine site are a combination of fresh water from the diversion channels and quarry runoff, and treated water from the water treatment plants. The water treatment plant flows are expected to vary based on the amount of water captured at the mine site, whereas the flows from the fresh water diversions are expected to vary according to natural flow patterns, with higher flows during the spring melt and fall rainy periods, and lower flows during the late summer and winter months. The total water released from the water treatment plants will be a function of the site surplus water and the change in water management pond storage. During drier climate conditions, the amount of water stored within the water management ponds will decrease, while during wetter climate conditions, the amount of water stored within the water management ponds will increase.

The 1st, 10th, 50th, 90th, and 99th percentile values of total water released from the water treatment plants are summarized on a monthly basis in Table 4.2 and on Figure 4.2. These results, which are based on model inputs of 76 different series of paired monthly temperature and precipitation values over the 20-year mine life, indicate that the total flow releases from the water treatment plants can vary from lows of 8 cfs during the mid and late winter months (1st percentile results) to highs of 45 cfs for much of the year (99th percentile results). The total flow releases from the water treatment plants increase in the spring melt season (approximately April through June) in response to increased runoff throughout the mine site, which triggers the requirement to treat and release more water. The total flow releases from the water treatment plants decrease during the winter months (October through March) for all percentiles and during the summer low flow periods (July through September) for the 1st and 10th percentiles.

Table 4.2 Total Release from the Water Treatment Plants to Downstream of the Mine Site - 1st, 10th, 50th, 90th, and 99th Percentiles

Month	Total Release from Water Treatment Plants (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
Jan	12	17	24	35	40
Feb	13	17	22	31	38
Mar	8	17	22	30	40
Apr	11	16	22	29	40
May	12	21	26	35	45
Jun	21	27	35	44	45
Jul	17	22	35	45	45
Aug	18	22	35	45	45
Sep	21	26	36	45	45
Oct	16	25	36	45	45
Nov	8	17	30	45	45
Dec	12	17	26	40	45
Annual Average	14	20	29	39	43

NOTES:

1. TOTAL RELEASE FROM WTP IS THE SUM OF THE FLOWS AVAILABLE FOR RELEASE FROM WTP#1 AND WTP#2 AFTER TREATED FLOW REQUIREMENTS TO THE PROCESS ARE SATISFIED.

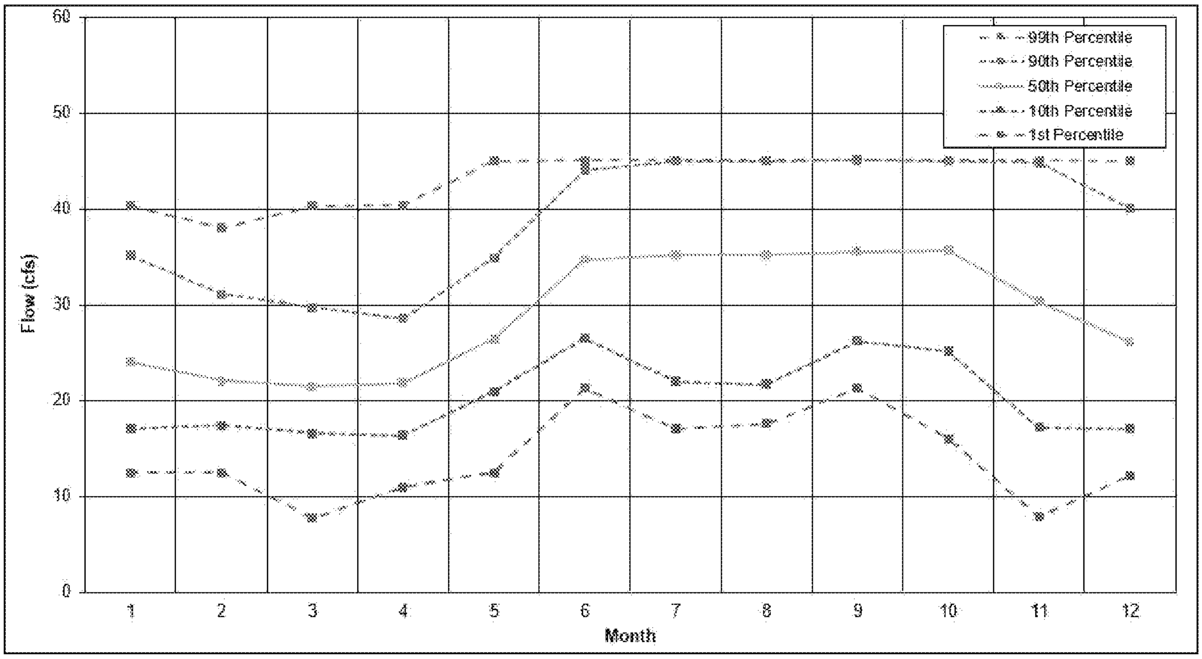


Figure 4.2 Total Flow Releases from the Water Treatment Plants to Points Downstream of the Mine Site: 1st, 10th, 50th, 90th, and 99th Percentile Results

The percentile results shown in Table 4.2 and on Figure 4.2 were calculated based on the full set of 76 model realizations, and do not specifically represent any one individual model realization. Three individual model realizations were selected to show the potential variation in water treatment plant flow releases. These realizations were not selected to match the percentile results shown in Table 4.2 and on Figure 4.2, but rather to represent relatively dry, average, and relatively wet annual climate conditions.

The total flow releases from the water treatment plants for the final years of operations for the three selected realizations are summarized on a monthly basis in Table 4.3 and on Figure 4.3. These results indicate that the total flow releases are similar during the low-flow period from January through April for all three climate scenarios; however, differences in the timing and magnitude of the spring snowmelt runoff dictate that flow releases from the water treatment plants differ during the spring (May through June). For instance, the releases are higher in May for the relatively dry scenario (realization #36) than for both the average (realization #5) and relatively wet scenarios (realization #10), but then the relative differences in flows change according to how the climate and runoff conditions vary throughout the year. On an annual basis, however, the average and relatively wet scenarios had higher total releases from the water treatment plants than the relatively dry scenario.

Table 4.3 Total Release from the Water Treatment Plants to Downstream of the Mine Site - Individual Realizations Representing Relatively Dry, Average, and Relatively Wet Conditions

Month	Total Release from WTP (cfs)		
	Relatively Dry Conditions (Realization #36)	Average Conditions (Realization #5)	Relatively Wet Conditions (Realization #10)
Jan	22	26	22
Feb	17	17	17
Mar	17	22	17
Apr	22	22	22
May	26	22	22
Jun	27	36	27
Jul	17	36	36
Aug	22	36	45
Sep	22	36	45
Oct	22	36	45
Nov	8	31	45
Dec	12	26	40
Annual Average	20	29	32

NOTES:

1. TOTAL RELEASE FROM THE WTPS IS THE SUM OF THE FLOWS AVAILABLE FOR RELEASE FROM WTP#1 AND WTP#2 AFTER TREATED FLOW REQUIREMENTS TO THE PROCESS ARE SATISFIED.

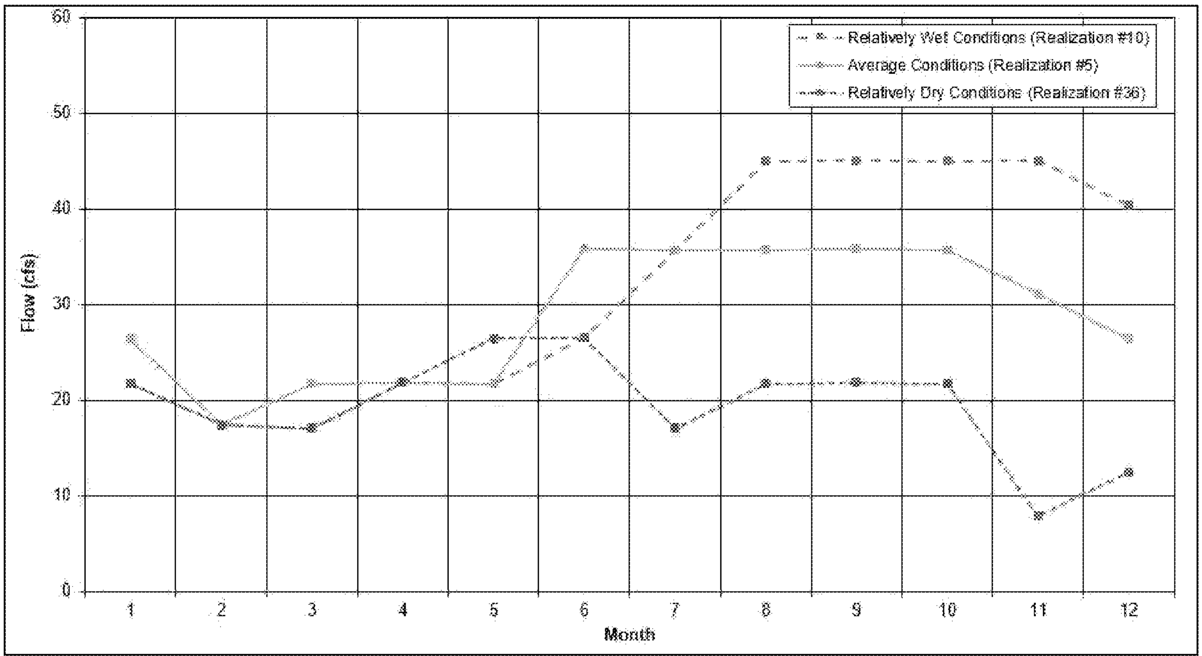


Figure 4.3 Total Release from the Water Treatment Plants to Downstream of the Mine Site for Individual Realizations Representing Relatively Dry, Average, and Relatively Wet Conditions

5.0 WATER QUALITY MODEL

5.1 GENERAL

A water quality model (WQ model) was developed to predict the influent water quality to the water treatment plants and the water quality within the water management ponds using a mass balance approach. The WQ model developed using Goldsim® and was built on the foundation of the Mine Plan Module, which provided the inflows, outflows, and storage volumes for each pond. Water quality predictions are provided for the following:

- WTP#1
- WTP#2
- OP WMP
- Main WMP
- Bulk TSF
- Bulk TSF Main SCP, and
- Pyritic TSF.

The water quality standards at each of the proposed discharge locations are summarized in Table 5.1. The water treatment plants will be designed to meet the specified discharge water quality standards.

5.2 METHODOLOGY

The mass balance calculations factor in the inflow loads (e.g., undisturbed runoff load, load transfer from other facilities, etc.) and outflow loads (e.g., load transfer to other facilities, loads trapped in the tailings voids, etc.) from the water management ponds. The monthly concentrations are a function of the constituent loads and the flow volumes associated with the inflow, outflow and storage components of the system, and based on the integration of the following:

- The monthly constituent concentrations within a pond are equal to the sum of the previous month's stored load and the current monthly loading divided by the previous month's stored volume plus the current month's inflow volume minus the evaporation.
- Loads removed from each facility by either pumping or seepage losses are determined using the monthly concentrations multiplied by the volumes of water being removed during each time step.
- The stored load for each monthly time step is the sum of the previous month's load and the incoming load minus the outgoing load.

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TABLE 5.1

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

WATER QUALITY STANDARDS IN RECEIVING WATER BODY

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Parameter	Units	Estimated Limits & Basis	
		Most Stringent	Basis
Aluminum (total)	ug/L	87	WQBEL-ALC
Antimony (total)	ug/L	6	WQBEL-DW
Arsenic (total)	ug/L	10	WQBEL-DW
Barium (total)	ug/L	2000	WQBEL-HH
Beryllium (total)	ug/L	4	WQBEL-HH
Boron (total)	ug/L	750	WQBEL-HH
Cadmium (H) (total)	ug/L	0.08	WQBEL-ALC
Chloride	ug/L	230000	WQBEL-ALC
Total Residual Chlorine	ug/L	11	WQBEL-ALC
Chromium (total)	ug/L	100	WQBEL-DW
Chromium III (H) (total)	ug/L	19.18	WQBEL-ALC
Chromium VI (dissolved)	ug/L	11	WQBEL-ALC
Cobalt (total)	ug/L	50	WQBEL-IR
Copper (H) (total)	ug/L	2.19	WQBEL-ALC
Cyanide (WAD)	ug/L	5.2	WQBEL-ALC
Fluoride	ug/L	1000	WQBEL-IR
Iron (total)	ug/L	1000	WQBEL-ALC
Lead (H) (total)	ug/L	0.39	WQBEL-ALC
Lithium (total)	ug/L	2500	WQBEL-IR
Manganese (total)	ug/L	50	WQBEL-HH
Mercury (total)	ug/L	0.012	WQBEL-ALC
Molybdenum (total)	ug/L	10	WQBEL-IR
Nickel (H) (total)	ug/L	12.87	WQBEL-ALC
Nitrate	ug/L	10000	WQBEL-DW
Nitrite	ug/L	1000	WQBEL-DW
Total Nitrate+Nitrite as N	ug/L	10000	WQBEL-DW
Selenium (total)	ug/L	5	WQBEL-ALC
Silver (H) (total)	ug/L	1.1	WQBEL-ALA
Thallium (total)	ug/L	1.7	WQBEL-HH
Vanadium (total)	ug/L	100	WQBEL-HH
Zinc (H) (total)	ug/L	28.95	WQBEL-ALA
TDS	mg/L	500	WQBEL-HH
pH	-	6.5 - 8.5	WQS-GP
TSS	mg/L	20	ELG-MA
DO	mg/L	> = 7.0	WQS-GP
Turbidity (NTU)	NTU	No greater than 5 NTU above natural turbidity	WQS-WS
Alkalinity	ug/L	> = 20,000	WQBEL-ALC
Ammonia as N	mg/L	4.36	WQBEL-ALC
Hardness	mg/L	100	see note 9 below
Sulfate	mg/L	250	WQS

\\KPL\VA-Prj$\1\01\00176\57\A\Report\4 - Water Management Report\Rev 1\Tables\[Estimated Discharge Criteria.xlsx]Table 5.1_WTP_Limits

ABBREVIATIONS:

WQBEL: Water Quality Based Effluent Limit
ELG: Effluent Limitation Guideline
(H): Hardness dependent criterion
(S): Selenite + Selenate dependent criterion
WQS: Water Quality Standards
HH: Human Health
ALA: Aquatic Life, Acute
ALC: Aquatic Life, Chronic
DW: Drinking Water
MA: Monthly Average
GP: Growth and Propagation of Fish
IR: Irrigation water
WS: Water supply

NOTES:

1. Water quality based effluent limits (WQBELs) are taken from *Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances* dated December 2008.
2. Water quality standards (WQS) are taken from *Alaska Water Quality Standards* (18 AAC 70) dated April 6, 2018.
3. Technology based effluent limits are take from *Effluent Limitation Guidelines, Subpart J* (40 CFR 440.104) for the Copper, Lead, Zinc, Gold, Silver, and Molybdenum subcategory.
4. Water quality standards for dissolved oxygen, turbidity, and pH are mandatory. Estimated limits are the most stringent of water supply, recreation, or growth and propagation standards. Temperature limits are also required, but dependent on habitat and seasonal considerations.
5. Hardness-dependent criteria (cadmium, copper, chromium III, lead, nickel, silver, zinc) are calculated using the estimated 15th percentile conditions for the receiving streams. The most stringent of the three proposed discharge locations is included in the table.
6. The acute selenium standard is based on the selenite/selenate fraction and was not calculated for this estimate. The chronic standard is used instead.
7. Ammonia: acute criterion is pH dependent; chronic criterion is temperature and pH dependent. Estimate based on pH 7.5 and temperature 14 C. Temperatures below 14C do not change the criterion.
8. The criteria in the table are the applicable regulatory criteria. More stringent discharge criteria may be used by the Pebble Partnership.
9. Based on the lowest 15th percentile hardness of the three proposed discharge locations.

1	06JUL'18	ISSUED WITH REPORT VA101-176/57-4	AS	JGC
REV	DATE	DESCRIPTION	PREP'D	RVW'D

5.3 WQ MODEL INPUTS AND ASSUMPTIONS

The following inputs and assumptions were used to develop the water quality model;

- Complete mixing under steady state conditions (i.e., no reactions or degradation occurs) for all facilities and flow streams except for the concentrations in the tailings slurry leaving the process plant and the concentrations in the Bulk TSF and Pyritic TSF, as directed by SRK and described below:
  - Solubility limits were applied to the Bulk TSF and Pyritic TSF in the WQ model as a load capping mechanism, whereby loads in excess of constraining solubility concentrations were removed from the available monthly stored loads in the facility and assumed to precipitate out of the solution and therefore no longer be available as an outgoing load.
  - Solubility limits were applied to aluminum, copper, iron, manganese, and sulphate concentrations leaving the process plant and to concentrations in the Bulk TSF and Pyritic TSF. Solubility limits were applied based on the following:
    - If the calculated concentration leaving the process plant, or the concentrations in the TSF supernatant pond, were greater than the solubility limits, then the solubility limits were applied; otherwise, the concentrations were calculated based on the influent load and flow.
    - For all other parameters, the outflow concentrations were calculated based on the influent load and flow.
- 95th percentile source terms were provided by SRK as parameter concentrations or loadings (SRK 2018). The source terms and source term assumptions are outlined in Table B1.1 and Table B1.2 in Appendix B1.
- Nitrate, Nitrite and Ammonia concentrations for the source terms were calculated based on the following equations:
  - Nitrate (ion) = 4.43 x Nitrate concentration (mg/L as N)
  - Nitrite = 0.02 x Nitrate (ion) concentration (mg/L), and
  - Ammonia = 0.01 x Nitrite concentration (mg/L).
- Total dissolved solids (TDS) values were calculated as the sum of alkalinity, chloride, fluoride, sulphate, calcium, magnesium, potassium, sodium and silica.
- Total hardness values were calculated based on the following equation:

$$TH = 2.5 \times Ca + 4.1 \times Mg$$

- Where, TH = total hardness concentration (mg/L as $CaCO_3$)
- Ca = calcium concentration (mg/L)
- Mg = magnesium concentration (mg/L)
- pH values were based on the range of pH indicated in the geochemical source terms (SRK 2018).
- The model assumes that the loading from the PAG waste rock in the Pyritic TSF is flushing term (SRK 2018)
- The following source terms were assumed for the Open Pit wall runoff:
  - Winter months: pre-tertiary non-potential acid generating load, and
  - Summer months: 1.75 Mft^2 area of the Open Pit was assumed as in-pit stockpile load and the remaining as pre-tertiary non-potential acid generating load.
- The water quality predictions represent conditions during the final year of operations.

- The outflow concentrations from the WTPs are defined in Table B1.3 in Appendix B1.

5.4 WQ MODEL RESULTS AND DISCUSSION

The maximum monthly predicted concentrations for the 50th percentile flow values – in combination with the 95th percentile source term concentrations or leadings – for flows to the water treatment plants and in each facility, for the final year of operations, are shown on Table B2.1 in Appendix B2.

The water quality feeding to the water treatment plants is defined by the OP WMP concentrations for WTP#1 and the Main WMP concentrations for WTP#2. The water quality predications for WTP#1 are dominated by the loading from the Open Pit dewatering activities. The maximum predicted concentrations within the OP WMP occur during the summer months because of the in-pit stockpile loads from the Open Pit.

The Main WMP is the main facility for managing the surplus water from the mine site, and the majority of the loading to the Main WMP is a function of the loading from the Bulk TSF and the Pyritic TSF. The maximum predicted concentrations in the Main WMP are, however, less than in the Bulk TSF and the Pyritic TSF because of the continuous removal of loads from the Main WMP via the reclaim water that is directed to the process and to WTP#2.

The bulk tailings slurry water from the process drives the loading within the Bulk TSF supernatant pond. Similarly, the pyritic tailings slurry water from the process drives the majority of the loading in the Pyritic TSF, with both the sludge reject and RO reject flows from the water treatment plants contributing to the loading. The flushing load from the PAG waste rock into the Pyritic TSF provides loading to the Pyritic TSF supernatant pond; however, the load from the PAG waste rock is not as great as that from the tailings slurry water.

The water treatment plants are being designed by others based on the flow rate results of the water balance model and the water quality predictions from the WQ model. The proposed operations of the water treatment plants and the estimated effluent water quality are not provided as part of this report, and will be completed by others.

6.0 SUMMARY

The key points presented in this report are summarized as follows:

- The mean annual temperature in the Project area is just below freezing, with freezing temperatures generally persisting from October through April, and conditions are quite wet, with mean annual precipitation varying throughout the project area but generally ranging from 45 in. to 55 in.
- Precipitation and runoff conditions in the Project area vary substantially throughout the year, and from year to year. The Project area experiences extended periods of wet and dry conditions related to climate cycles.
- Groundwater plays a prominent role in the flow patterns of all the creeks and rivers in the Project area.
- The primary objectives of the water management plan are:
    - To minimize mine drainage water by diverting freshwater and stormwater as much as possible.
    - To describe how water will be managed to assure integrity of impoundments in all conditions.
    - To assure adequate water for operation of the Process Plant and associated support facilities.
    - To treat stormwater for sediment to meet effluent limitations.
    - To capture all mine drainage and process water and treat it in water treatment plants to meet water quality standards in the receiving water body.
- Large water management ponds and variable water treatment rates will be used to ensure that the water management objectives can be achieved under the full range of possible climate and runoff conditions.
- All water management facilities will have provisions in place to handle IDF flows either through storage or spillways.
- Treated water in excess of process requirements will be released to the environment at three points downstream of the mine footprint, one each in the NFK River, SFK River, and UT Creek watersheds.

7.0 REFERENCES

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8.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

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APPENDIX A

Water Balance Flow Schematic And Average Annual Flow Balance

(Pages A-1 to A-3)

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TABLE A.1

PEBBLE LIMITED PARTNERSHIP
PEBBLE PROJECT

AVERAGE ANNUAL FLOW BALANCE

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Flow Path Number and Description		Average Annual Flow (cfs) Relatively Dry Conditions (Realization #36)	Average Conditions (Realization #5)	Relatively Wet Conditions (Realization #10)
Open Pit				
Open Pit Inflows				
1	Direct Precipitation	2	3	4
2	Undisturbed Surface Runoff	<1	<1	1
3	Diversion Channel Leakage	<1	1	2
4	Groundwater	6	6	6
5	Additional Snowblow	1	1	1
	Subtotal Inflows	**9**	**11**	**14**
Open Pit Outflows				
6	Dewatering to OP WMP	9	11	14
	Subtotal Outflows	**9**	**11**	**14**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Open Pit Water Management Pond (OP WMP)				
OP WMP Inflows				
7	Direct Precipitation	<1	<1	1
8	Undisturbed Surface Runoff	<1	<1	1
6	Dewatering from Open Pit	9	11	14
	Subtotal Inflows	**9**	**11**	**15**
OP WMP Outflows				
9	Pond Evaporation	<1	<1	<1
10	Dust Suppression	<1	<1	<1
11	Surplus to Main WMP	0	1	5
12	Surplus to WTP#1	9	10	11
	Subtotal Outflows	**9**	**11**	**16**
	Change in Storage	**0**	**0**	**0**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Mill/Process				
Process Inflows				
13	Water in Ore	2	2	2
14	Treated Water	3	3	3
15	Reclaim Water from Main WMP	48	48	48
	Subtotal Inflows	**53**	**53**	**53**
Process Outflows				
16	Water in Concentrate	<1	<1	<1
17	Bulk Tailings Slurry Water	46	46	46
18	Pyritic Tailings Slurry Water	7	7	7
	Subtotal Outflows	**53**	**53**	**53**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Power Plant				
Power Plant Inflows				
19	Treated Water for Cooling Towers	3	3	3
	Subtotal Inflows	**3**	**3**	**3**
Power Plant Outflows				
20	Cooling Tower Evaporation	2	2	2
21	Blowdown Water to Main WMP	1	1	1
	Subtotal Outflows	**3**	**3**	**3**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Pyritic Tailings and PAG Waste Rock Management Facility (Pyritic TSF)				
Pyritic TSF Inflows				
22	Direct Precipitation	2	4	7
23	Undisturbed Surface Runoff	<1	1	2
24	Diversion Channel Leakage	<1	<1	<1
25	Seepage Collection Recycle Ponds	<1	<1	1
55 + 57	Reject Flows from WTPs	<1	1	1
18	Pyritic Tailings Slurry Water	7	7	7
	Subtotal Inflows	**9**	**13**	**18**
Pyritic TSF Outflows				
26	Pond Evaporation	1	1	1
27	Pyritic Tailings Void Losses	2	2	2
28	PAG Waste Rock Void Losses	1	1	1
29	Surplus to Main WMP	5	8	8
	Subtotal Outflows	**9**	**12**	**12**
	Change in Storage	**0**	**1**	**5**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk Tailings Management Facility (Bulk TSF)				
Bulk TSF Inflows				
30	Direct Precipitation on Supernatnat Pond	1	2	6
31	Undisturbed Surface Runoff	2	5	10
32	Diversion Channel Leakage	<1	<1	<1
33	Recycle from Seepage Collection Recycle Ponds	1	2	3
34	Bulk Tailings Beach Runoff	4	9	16
17	Bulk Tailings Slurry Water	46	46	46
	Subtotal Inflows	**54**	**64**	**81**
Bulk TSF Outflows				
35	Pond Evaporation	1	1	1
36	Bulk Tailings Void Losses	17	17	17
37	Seepage through main embankment	9	9	9
38	Surplus to Main WMP	28	37	50
	Subtotal Outflows	**55**	**64**	**77**
	Change in Storage	**-1**	**0**	**4**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**

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TABLE A.1 (continued)

PEBBLE LIMITED PARTNERSHIP
PEBBLE PROJECT

AVERAGE ANNUAL FLOW BALANCE

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Flow Path Number and Description		Average Annual Flow (cfs) Relatively Dry Conditions (Realization #36)	Average Conditions (Realization #5)	Relatively Wet Conditions (Realization #10)
Bulk TSF Main Embankment Seepage Collection Pond (Bulk TSF Main SCP)				
Seepage Pond Inflows				
39	Direct Precipitation	<1	<1	1
40	Undisturbed Surface Runoff	1	3	5
41	Diversion Channel Leakage	<1	<1	1
42	Bulk TSF Main Embankment Runoff	1	1	2
37	Seepage through main embankment	9	9	9
	Subtotal Inflows	**11**	**13**	**18**
Seepage Pond Outflows				
43	Pond Evaporation	<1	<1	<1
44	Surplus to Main WMP	11	13	14
	Subtotal Outflows	**11**	**13**	**14**
	Change in Storage	**0**	**0**	**4**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Bulk TSF South Embankment Seepage Collection Pond				
Seepage Pond Inflows				
45	Undisturbed Surface Runoff	1	1	2
46	Diversion Channel Leakage	<1	<1	1
47	Bulk TSF South Embankment Runoff	<1	<1	<1
	Subtotal Inflows	**1**	**1**	**3**
Seepage Pond Outflows				
33	Recycle to Bulk TSF	1	1	3
	Subtotal Outflows	**1**	**1**	**3**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Main Water Management Pond (Main WMP)				
Main WMP Inflows				
48	Direct Precipitation	1	4	7
49	Undisturbed Surface Runoff	1	3	5
50	Diversion Channel Leakage	<1	<1	1
51	Mill Site Runoff	<1	1	1
52	Pyritic TSF Main Embankment Runoff	<1	1	1
11	Surplus from OP WMP	0	1	5
29	Surplus from Pyritic TSF	5	8	8
38	Surplus from Bulk TSF	28	37	50
44	Surplus from Bulk TSF Main SCP	11	13	14
21	Blowdown Water to Main WMP	1	1	1
	Subtotal Inflows	**47**	**69**	**93**
Main WMP Outflows				
53	Pond Evaporation	1	1	1
15	Reclaim Water to Process	48	48	48
54	Water to WTP#2	17	25	28
	Subtotal Outflows	**66**	**74**	**77**
	Change in Storage	**-19**	**-5**	**16**
	Balance (Inflows - Outflows - Change in Storage)	**0**	**0**	**0**
Water Treatment Plant #1 (WTP #1)				
WTP#1 Inflows				
12	Surplus from OP WMP	9	10	11
	Subtotal Inflows	**9**	**10**	**11**
WTP#1 Outflows				
55	Reject Flows	<1	<1	<1
56	Flows Released to Environment	9	10	11
	Subtotal Outflows	**9**	**10**	**11**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Water Treatment Plant #2 (WTP #2)				
WTP#2 Inflows				
54	Surplus from Main WMP	17	25	28
	Subtotal Inflows	**17**	**25**	**28**
WTP#2 Outflows				
57	Reject Flows	<1	<1	1
14	Treated Water to Process	3	3	3
19	Treated Water to Power Plant Cooling Towers	3	3	3
58	Flows Released to Environment	11	19	21
	Subtotal Outflows	**17**	**25**	**28**
	Balance (Inflows - Outflows)	**0**	**0**	**0**
Diverted Flows				
59	Runoff from Quarry B	1	3	5
60	Runoff from Quarry C	1	1	3
61	Diversion Channel Flow	3	6	12
	Total Diverted Flows to Downstream Environment	**5**	**10**	**20**
Flows Released to Downstream Environment				
59 + 60 + 61	Total Diverted Flows to Downstream Environment	5	10	20
56	Treated Flows from WTP#1	9	10	11
58	Treated Flows from WTP#2	11	19	21
	Total Flows Released to Downstream Environment	**25**	**39**	**52**

\\KPL\VA-Prj$\1\01\00176\57\A\Data\Water Management Plan\Area E and North Pond Optimization\[Water Balance Schematic_WBM011_byRealization.xlsx]Table_WaterBalanceResults

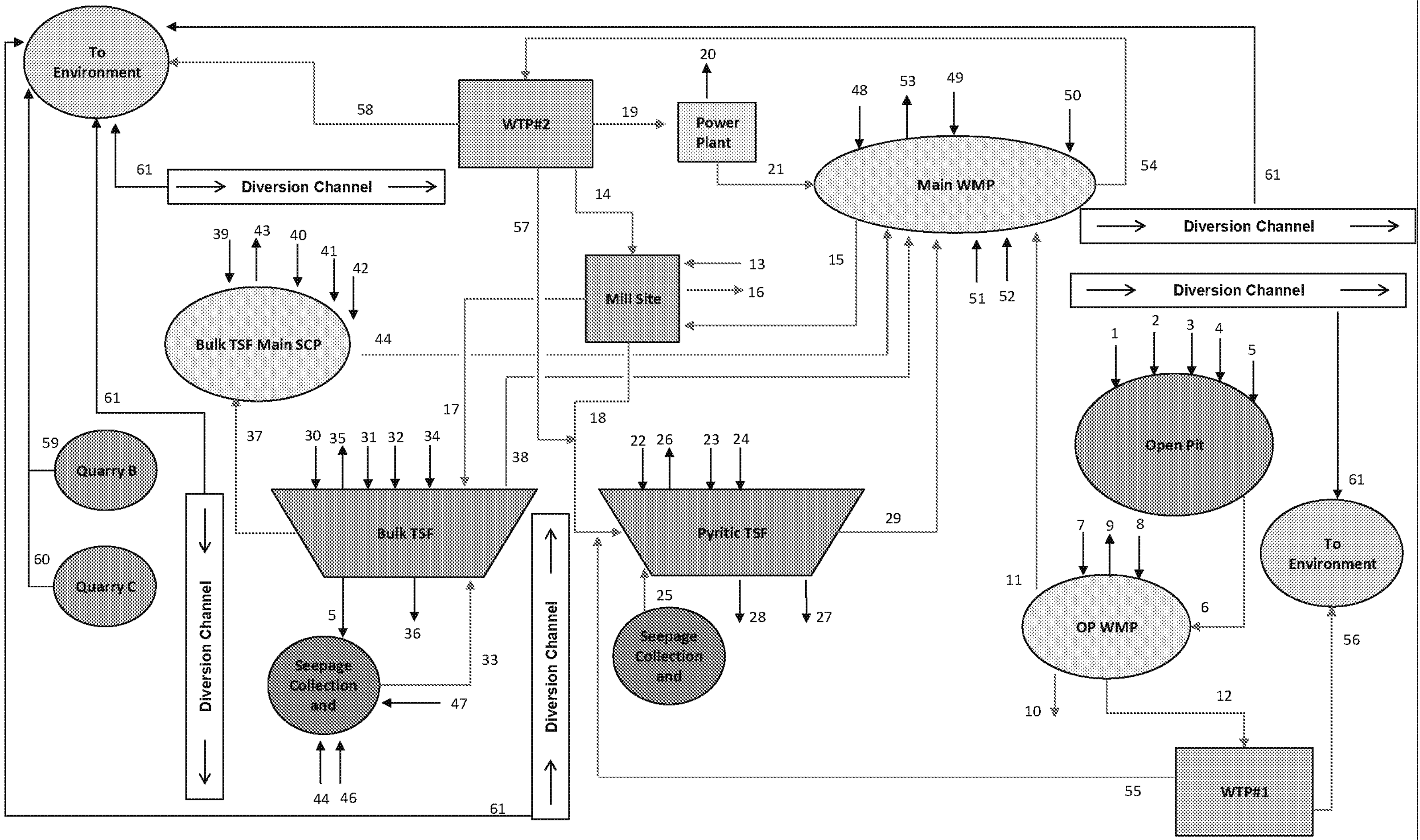
NOTES:

1. FLOW PATH NUMBER CORRESPONDS TO FLOW SCHEMATIC PRESENTED ON FIGURE A.1.
2. CHANGE IS STORAGE WITHIN THE PONDS ARE A FUNCTION OF THE WATER MANAGEMENT OPERATING CRITERIA. A CHANGE IN STORAGE INDICATES IF THE POND HAS ACCUMULATED OR DECREASED POND VOLUME FROM THE START OF THE YEAR.

0	06JUL'18	ISSUED WITH REPORT	AS	LJG
REV	DATE	DESCRIPTION	PREP'D	RVW'D

NOTES:

1. FLOW PATH NUMBERS CORRESPOND WITH FLOW VALUES SUMMARIZED IN TABLE A.1.



LEGEND:

3 FLOW PATH NUMBER

RUNOFF, GROUNDWATER, AND SEEPAGE PATHWAY

PUMPED FLOW

0	06JUL'18	ISSUED WITH REPORT	AS	LJG
REV	DATE	DESCRIPTION	PREP'D	RVW'D

PEBBLE LIMITED PARTNERSHIP

PEBBLE PROJECT

WATER BALANCE FLOW SCHEMATIC - OPERATIONS

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P/A NO. VA101-176/57 REF. NO. 4

FIGURE A.1 REV 0

APPENDIX B

Water Quality Model Inputs And Results

Appendix B1

Water Quality Model Source Terms and Assumptions

Appendix B2

Water Quality Model Results

APPENDIX B1

Water Quality Source Terms And Assumptions

(Pages B1-1 to B1-3)

![Knight Piésold Consulting]

TABLE B1.1

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

WATER QUALITY SOURCE TERMS AND ASSUMPTIONS
95TH PERCENTILE GEOCHEMICAL SOURCE TERMS

7/6/2018 9:04

Parameters	Background				Other Rock				Open Pit					Tailings						Area E
	Direct Precipitation	Non-Contact Surface Water	Non-Contact Surface Water	Ground Water	Waste Rock	Waste Rock	Quarried Rock Fill (Dams)	Quarried Rock Fill (Dams)	Wall Runoff	Wall Runoff	Wall Runoff	In-Pit Stockpile	In-Pit Stockpile	Bulk Tailings Water	Fresh Ore Leaching + reagent	Rougher tailings	Ore	Tailings Pond Adjustment	Rougher Tailings Sand Wedge	PAG WR is 17% of facility area
		NFK (NK119A)	SFK SK100F	Pit area	Tertiary	Tertiary	Non-Acidic	Non-Acidic	Pre-Tertiary - Non-Acidic	Pre-Tertiary - Acidic	Tertiary - Non-Acidic	Non-Acidic	Non-Acidic	Supernatant		Runoff	Entrained moisture	Pond	Seepage	Total Load
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/t of new rock	mg/L	mg/t of new rock	mg/L	mg/L	mg/L	mg/L	mg/t of new rock	mg/L	mg/t of ore	mg/m2/week	mg/L	mg/L	mg/L	kg/year
pH	5.5	6.5	6.8	6.7	7.7	-	8.4	-	8.1	3.5	8.2	8.0	-	8.0	-	-	6.7	8.0	8.6	-
TDS	-	31.5	42.6	44.4	2158.0	-	3600.3	-	286.0	453.0	241.0	4473.2	-	198.0	-	378.3	44.4	-	4136.6	1285207.1
Alkalinity	-	14.6	18.0	33.0	26.4	-	490.0	-	49.3	-	69.0	800.0	-	97.4	217086.5	216.3	33.0	-	770.0	23403.9
Acidity	-	2.5	3.8	7.5	5.8	-	-	-	7.1	305.6	0.5	24.9	-	-	-	-	7.5	-	7.5	27760.7
Chloride	-	0.622	0.711	0.804	23.000	-	8.300	-	2.242	6.935	2.260	23.000	-	17.000	2068.840	1.684	0.804	-	9.300	6042.718
Fluoride	-	0.032	0.040	0.072	0.863	-	0.870	-	0.316	0.447	0.112	1.800	-	0.480	-	0.547	0.072	-	0.900	1931.820
Sulfate	-	1.2	7.8	4.9	1456.2	-	2350.1	-	87.5	276.8	29.2	2350.1	-	159.5	921809.6	66.6	4.9	2350.1	2350.1	795940.3
Aluminum	-	0.0363	0.0544	0.0034	0.0487	-	1.3000	-	0.0011	22.9945	0.0015	2.6000	-	0.0109	478.2510	0.3845	0.0034	0.0006	2.5000	980.5286
Antimony	-	0.0001	0.0001	0.0000	0.2000	-	0.1500	-	0.0022	0.0010	0.0183	0.2000	-	0.0025	2.3607	0.0209	0.0000	-	0.2000	76.2858
Arsenic	-	0.0002	0.0004	0.0004	0.1898	-	0.1900	-	0.0196	0.0341	0.0430	0.4000	-	0.0020	3.3020	0.0961	0.0004	-	0.2600	66.5914
Barium	-	0.0025	0.0049	0.0064	6.1823	-	0.1000	-	0.1391	0.0600	1.0025	0.3600	-	0.0226	41.5838	0.0427	0.0064	-	0.1500	374.7911
Berylium	-	0.00001	0.00001	0.00002	0.00500	-	0.00500	-	0.00002	0.00852	0.00005	0.00500	-	0.00020	33.22308	0.00064	0.00002	-	0.00500	2.41709
Bismuth	-	0.00013	0.00010	0.00002	0.10811	-	0.10000	-	0.00005	0.00005	0.00005	0.20000	-	0.00050	3.06842	0.00160	0.00002	-	0.10000	6.04272
Boron	-	0.00158	0.00153	0.00150	0.73000	-	0.50000	-	0.07779	0.15069	0.19222	0.73000	-	0.02200	175.52728	0.03202	0.00150	-	0.52000	209.65366
Cadmium	-	0.00001	0.00001	0.00002	0.01097	-	0.00550	-	0.00202	0.02638	0.00023	0.22000	-	0.00006	13.57445	0.00017	0.00002	-	0.01000	7.16786
Calcium	-	3.9	6.1	13.8	538.1	-	760.0	-	30.4	9.9	25.3	940.0	-	66.2	153076.1	71.6	13.8	-	770.0	288138.4
Chromium	-	0.0002	0.0003	0.0005	0.0200	-	0.0200	-	0.0008	0.0017	0.0011	0.0200	-	0.0005	3.0684	0.0016	0.0005	-	0.0200	6.1232
Cobalt	-	0.0001	0.0001	0.0001	0.0219	-	0.0490	-	0.0204	0.2515	0.0006	0.8800	-	0.0006	31.4835	0.0003	0.0001	-	0.0500	55.0902
Copper	-	0.0004	0.0021	0.0004	0.0249	-	0.1600	-	0.0064	6.3730	0.0041	1.3000	-	0.0102	29924.1742	0.0174	0.0004	0.0100	0.3700	1395.2035
Iron	-	0.1500	0.5480	0.0200	0.0021	-	1.7000	-	0.0020	38.5700	0.0020	16.0000	-	0.0300	10692.5014	0.1011	0.0200	0.0020	1.8000	366.3925
Lead	-	0.0002	0.0003	0.0001	0.0120	-	0.0500	-	0.0001	0.0081	0.0005	0.0620	-	0.0001	20.5394	0.0002	0.0001	-	0.0500	3.4251
Magnesium	-	0.7340	1.4800	1.0700	48.8700	-	99.0000	-	10.0300	1.9050	2.5080	120.0000	-	15.6000	84592.4968	18.1849	1.0700	-	99.0000	92003.8556
Manganese	-	0.00899	0.0493	0.441	1.492907048	-	2.4	-	1.94842138	13.205	0.14084546	6.2	-	0.56	18431.34201	0.2133745	0.441	2.000	2.9	5251.365439
Mercury	-	0.000001	0.000001	0.000001	0.002170	-	0.000500	-	0.000004	0.000011	0.000003	0.006200	-	0.000010	0.101264	0.000036	0.000001	-	0.000500	0.135523
Molybednum	-	0.000158	0.000509	0.000256	0.445513	-	9.800000	-	0.051323	0.008362	0.150278	7.800000	-	0.038300	7.454516	0.068144	0.000256	-	12.000000	138.326226
Nickel	-	0.000220	0.000354	0.000647	0.109241	-	0.050000	-	0.013449	0.195004	0.002342	0.320000	-	0.002120	91.866767	0.001939	0.000647	-	0.050000	36.247710
Potassium	-	0.206	0.373	0.342	50.000	3282.126	36.000	2597.446	4.692	0.000	4.700	-	2597.446	31.300	34793.196	21.037	0.342	-	36.000	19793.459
Selenium	-	0.000140	0.000413	0.001090	0.217050	-	0.055000	-	0.015695	0.125842	0.016380	0.048000	-	0.006000	19.801217	0.003438	0.001090	-	0.055000	42.301751
Silver	-	0.000005	0.000004	0.000006	0.002210	-	0.010000	-	0.000030	0.000092	0.000042	0.010000	-	0.000017	0.068625	0.000032	0.000006	-	0.010000	0.144415
Sodium	-	2.03	2.40	2.47	487.38	45271.20	110.00	3978.95	8.70	0.01	9.75	-	3978.95	28.40	104093.88	6.89	2.47	-	130.00	30321.02
Thallium	-	0.00001	0.00001	0.00001	0.00100	-	0.00049	-	0.00080	0.00216	0.00046	0.00100	-	0.00007	0.62473	0.00017	0.00001	-	0.00050	1.07323
Silicon	-	5.43000	4.02000	5.88000	32.64000	-	31.00000	-	-	-	-	47.00000	-	2.80000	3520.69974	-	5.88000	-	32.00000	-
Tin	-	0.00006	0.00006	0.00010	0.02296	-	0.19000	-	0.00017	0.00016	0.00020	0.03000	-	0.00010	0.61368	0.00034	0.00010	-	0.20000	32.19700
Vanadium	-	0.00033	0.00035	0.00055	0.03000	-	0.03000	-	0.00081	0.00151	0.01000	0.03000	-	0.00050	3.46735	0.01000	0.00055	-	0.03000	7.62389
Zinc	-	0.00167	0.00317	0.00150	0.24258	-	0.97000	-	0.36342	2.03400	0.00780	8.80000	-	0.00290	1828.50054	0.00458	0.00150	-	1.90000	1267.43960
Nitrate_N	-	-	-	-	-	-	-	4672.5	-	-	-	-	389.4	-	-	-	-	-	-	-
Nitrate	-	-	-	-	-	-	-	20684.2	-	-	-	-	1723.7	-	-	-	-	-	-	-
Nitrite	-	-	-	-	-	-	-	413.7	-	-	-	-	34.5	-	-	-	-	-	-	-
Ammonia	-	-	-	-	-	-	-	467.2	-	-	-	-	38.9	-	-	-	-	-	-	-

M:\1\01\00176\57\A\Report\4 - Water Management Report\Rev 0\Appendix B - Water Quality Model Inputs and Results\[Appendix B1.xlsx]Table 1_WQ_Source_Terms

NOTES:

1. SOURCE TERM VALUES WERE PROVIDED BY SRK (DATED 20 JUNE, 2018).

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	05JUL'18	ISSUED WITH REPORT VA101-176/57-4	KT	AS

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TABLE B1.2

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

WATER QUALITY SOURCE TERMS AND ASSUMPTIONS
SOURCE TERM ASSUMPTIONS

7/6/2018 9:08

Flow Path	Description	Assigned Water Quality	Ratios	Source
		Open Pit		
1 and 5	Direct Precipitation and Additional Snowblow	Wall Runoff (Pre-Tertiary-Non-Acidic) during winter months, In pit Stockpile (Non-Acidic) during summer months (1.75 Mft^2) and remaining area Pre-Tertiary-Non-Acidic	-	PLP- June 28, 2018
2	Undisturbed Surface Runoff	Non-Contact Surface Water (SFK SK100F)	100%	SRK - June 20, 2018
3	Diversion Channel Leakage	Non-Contact Surface Water (SFK SK100F)	100%	SRK - June 20, 2018
4	Groundwater	Groundwater (Pit area)	100%	SRK - June 20, 2018
		Open Pit Water Management Pond		
7	Direct Precipitation	Direct Precipitation	100%	SRK - June 20, 2018
9	Evaporation	None	100%	-
8	Undisturbed Surface Runoff	Non-Contact Surface Water (SFK SK100F)	100%	SRK - June 20, 2018
10	Dust Suppression	Concentration in the Open Pit Water Management Pond	100%	GoldSim Model Calculation
6	Dewatering from Open Pit	Concentration in the Open Pit	100%	GoldSim Model Calculation
		Water Treatment Plant #1 (WTP#1)		
12	Surplus to WTP#1	Concentration in the Open Water Management Pond	100%	GoldSim Model Calculation
55	Reject Flows	WTP#1 - Sludge and Reject Concentrations	100%	HDR - January 4,2018
		Mill Site		
14	Treated Water	Outflow Concentration from WTP	100%	HDR - January 4,2018
13	Water in Ore	Ore (Entrained Moisture)	100%	SRK - June 20, 2018
16	Water in Concentrate	Combined Concentrations after applying Tailings Pond Adjustment (Pond)	100%	SRK - June 20, 2018
15	Reclaim Water from Main WMP	Concentration in the Main Water Management Pond	100%	GoldSim Model Calculation
		Bulk Tailings Management Facility (Bulk TSF)		
30	Direct Precipitation on Supernatant Pond	Direct Precipitation	100%	SRK - June 20, 2018
35	Evaporation	None	100%	-
31	Undisturbed Surface Runoff	Non-Contact Surface Water (NFK (NK119A))	100%	SRK - June 20, 2018
32	Diversion Channel Leakage	Non-Contact Surface Water (NFK (NK119A))	100%	SRK - June 20, 2018
17	Bulk Tailings Slurry Water	Calculated Concentrations in the Mill after applying Tailings Pond Adjustment (Pond)	100%	GoldSim Model Calculation
36	Bulk Tailings Void Losses	Calculated Concentrations in the Mill after applying Tailings Pond Adjustment (Pond)	100%	GoldSim Model Calculation
34	Bulk Tailings Beach Runoff	Rougher Tailings (Runoff)	100%	SRK - June 20, 2018
33	Recycle from Seepage Collection Pond Recycle	Concentration in the Seepage Collection Pond	100%	GoldSim Model Calculation
		Bulk TSF South Embankment Seepage Collection Pond		
45	Undisturbed Runoff	Non-Contact Surface Water (NFK (NK119A))	100%	SRK - June 20, 2018
46	Diversion Channel Leakage	Non-Contact Surface Water (NFK (NK119A))	100%	SRK - June 20, 2018
5	Seepage	Concentration in the Bulk TSF	100%	GoldSim Model Calculation
47	Bulk TSF South Embankment Runoff	Quarried Rock Fill (Dams) (Non-Acidic)	100%	SRK - June 20, 2018
		Bulk TSF Main Embankment Seepage Collection Pond (Bulk TSF Main SCP)		
39	Direct Precipitation	Direct Precipitation	100%	SRK - June 20, 2018
2	Evaporation	None	100%	-
40	Undisturbed Surface Runoff	Non-Contact Surface Water (NFK (NK119A))	100%	SRK - June 20, 2018
41	Diversion Channel Leakage	Non-Contact Surface Water (NFK (NK119A))	100%	SRK - June 20, 2018
37	Seepage through main Embankment	Rougher Tailings Sand Wedge (Seepage)	100%	SRK - June 20, 2018
42	Bulk TSF Main Embankment Runoff	Quarried Rock Fill (Dams) (Non-Acidic)	100%	SRK - June 20, 2018
		Pyritic Tailings and PAG Waste Rock Management Facility (Pyritic TSF)		
22	Direct Precipitation	Direct Precipitation	100%	SRK - June 20, 2018
26	Evaporation	None	100%	
23	Undisturbed Surface Runoff	Non-Contact Surface Water (NFK (NK119A))	100%	SRK - June 20, 2018
24	Diversion Channel Leakage	Non-Contact Surface Water (NFK (NK119A))	100%	SRK - June 20, 2018
18	Pyritic Tailings Slurry Water	Calculated Concentrations after applying Tailings Pond Adjustment (Pond) to the Pyritic Slurry and WTP Sludge/Rejects	100%	GoldSim Model Calculation
	PAG Waste Rock	PAG WR 17% of Facility Area	100%	SRK - June 20, 2018
55+57	Reject Flows from WTP's	WTP's - Sludge and Reject Concentrations	100%	HDR - January 4,2018
27	Pyritic Tailings Void Losses	Calculated Concentrations in the Mill after applying Tailings Pond Adjustment (Pond) to the Pyritic Slurry and WTP Rejects	100%	GoldSim Model Calculation
28	PAG Waste Rock Voids	Calculated Concentrations in the Mill after applying Tailings Pond Adjustment (Pond) to the Pyritic Slurry and WTP Rejects	100%	GoldSim Model Calculation
		Main Water Management Pond (Main WMP)		
48	Direct Precipitation	Direct Precipitation	100%	SRK - June 20, 2018
53	Evaporation	None	100%	-
49	Undisturbed Surface Runoff	Non-Contact Surface Water (NFK (NK119A))	100%	SRK - June 20, 2018
50	Diversion Channel Leakage	Non-Contact Surface Water (NFK (NK119A))	100%	SRK - June 20, 2018
38	Surplus from Bulk TSF	Concentration in Bulk TSF	100%	GoldSim Model Calculation
29	Surplus from Pyritic TSF	Concentration in Pyritic TSF	100%	GoldSim Model Calculation
44	Surplus Water from Bulk TSF Main SCP	Concentration in the Main Embankment Seepage Collection Pond	100%	GoldSim Model Calculation
21	Blow Down Water to Main WMP	Outflow Concentration from WTP#2	100%	HDR - January 4,2018
51	Mill Site Runoff	Quarried Rock Fill (Dams) (Non Acidic)	100%	SRK - June 20, 2018
52	Pyritic TSF Main Embankment Runoff	Quarried Rock Fill (Dams) (Non-Acidic)	100%	SRK - June 20, 2018
11	Surplus from OP WMP	Concentration in the Open Pit Water Management Pond	100%	GoldSim Model Calculation
		Power Plant		
20	Evaporation	None	100%	-
19	Cooling Tower Evaporation	Outflow Concentration from WTP#2	100%	HDR - January 4,2018
		Water Treatment Plant # 2 (WTP#2)		
54	Surplus Water from Main WMP	Concentration in the Main Water Management Pond	100%	GoldSim Model Calculation
55	Reject Flows	WTP#2 - Sludge and Reject Concentrations	100%	HDR - January 4,2018
		To Environment		
58 and 56	Treated Water to Environment	Outflow Concentration from WTP#1 and WTP#2	100%	HDR - January 4,2018
61	Diversion Channel to Environment	Non-Contact Surface Water (NFK (NK119A)/SFK (SK100F))	100%	SRK - June 20, 2018
59+60	Quarry Diversions to Environment	Quarried Rock Fill (Dams) (Non Acidic)	100%	SRK - June 20, 2018

M:\1\01\00176\57\A\Report\4 - Water Management Report\Rev 0\Appendix B - Water Quality Model Inputs and Results\[Appendix B1.xlsx]Table 2_WQ_Source_Term_Assump

NOTES:

1. FLOW PATH NUMBERING AND DESCRIPTION WERE BASED ON THE FIGURE A.1 AND TABLE A.1.
2. WATER QUALITY WAS BASED ON 95th PERCENTILE SOURCE TERMS PROVIDED BY SRK (2018).
3. MODEL ASSUMES RETURN OF SLUDGE, REJECT AND OUTFLOW CONCENTRATIONS WERE PROVIDED BY HDR (2018a).

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TABLE B1.3

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

WATER QUALITY SOURCE TERMS AND ASSUMPTIONS
OUTFLOW CONCENTRATIONS FROM THE WATER TREATMENT PLANT

Parameters	Units	WTP Outflows
pH	-	7
TDS	mg/l	467
Alkalinity	mg/l	21
Acidity	mg/l	0
Chloride	mg/l	4.8
Fluoride	mg/l	0.4
Sulfate	mg/l	151
Aluminum	mg/l	0.0083
Antimony	mg/l	0.0034
Arsenic	mg/l	0.0042
Barium	mg/l	0.058
Berylium	mg/l	0.0012
Bismuth	mg/l	0.000007
Boron	mg/l	5.3
Cadmium	mg/l	0.000049
Calcium	mg/l	45.7
Chromium	mg/l	0.0002
Cobalt	mg/l	0.0038
Copper	mg/l	1.2E-13
Iron	mg/l	0.000045
Lead	mg/l	0.000024
Magnesium	mg/l	5
Manganese	mg/l	0.0016
Mercury	mg/l	0.0000061
Molybednum	mg/l	0.005
Nickel	mg/l	0.0001
Potassium	mg/l	29.4
Selenium	mg/l	0.005
Silver	mg/l	1.9E-10
Sodium	mg/l	183
Thallium	mg/l	0.0000045
Silicon	mg/l	22.1
Tin	mg/l	0.000015
Vanadium	mg/l	0.0048
Zinc	mg/l	0.00032
Nitrate_N	mg/l	7.3
Nitrate	mg/l	1
Nitrite	mg/l	0.01
Ammonia	mg/l	1.1

M:\1\01\00176\57\A\Report\4 - Water Management Report\Rev 0\Appendix B - Water Quality Model Inputs and Results\[Appendix B1.xlsx]Table 3_WTP_Effluent

NOTES:

1. SOURCE HDR 2017.
2. VALUES BASED ON 95TH PERCENTILE SOURCE TERMS AND 50TH PERCENTILE FLOWS.

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APPENDIX B2

Water Quality Model Results

(Page B2-1)

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TABLE B2.1

THE PEBBLE PARTNERSHIP
PEBBLE PROJECT

WATER QUALITY RESULTS FOR OPERATIONS - END OF MINE LIFE
BASE CASE - 50TH PERCENTILE

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Parameters	Units	WTP#1 Inflows	WTP#2 Inflows	Open Pit Water Management Pond	Bulk TSF	Main Embankment Seepage Collection Pond	Pyritic TSF	Main Water Management Pond
		Maximum Monthly	Maximum Monthly	Maximum Monthly	Maximum Monthly	Maximum Monthly	Maximum Monthly	Maximum Monthly
pH	-	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8
TDS	mg/l	267	1,677	267	2,493	3,940	2,933	1,677
Alkalinity	mg/l	56	252	56	395	746	234	252
Acidity	mg/l	7.42	2.53	7.42	2.49	7.11	6.09	2.53
Chloride	mg/l	1.98	9.56	1.98	19.79	8.86	12.02	9.56
Fluoride	mg/l	0.21	0.35	0.21	0.49	0.86	0.65	0.35
Sulfate	mg/l	109	973	109	1,415	2,250	1,873	973
Aluminum	mg/l	0.0947	0.2514	0.0947	0.0006	2.4350	0.0006	0.2514
Antimony	mg/l	0.007	0.036	0.007	0.026	0.193	0.061	0.036
Arsenic	mg/l	0.020	0.047	0.020	0.035	0.252	0.073	0.047
Barium	mg/l	0.070	0.058	0.070	0.080	0.145	0.127	0.058
Berylium	mg/l	0.0002	0.0197	0.0002	0.0455	0.0048	0.0250	0.0197
Bismuth	mg/l	0.006	0.019	0.006	0.012	0.096	0.036	0.019
Boron	mg/l	0.05	0.18	0.05	0.26	0.50	0.25	0.18
Cadmium	mg/l	0.0073	0.0099	0.0073	0.0186	0.0097	0.0206	0.0099
Calcium	mg/l	45	228	45	275	737	399	228
Chromium	mg/l	0.001	0.005	0.001	0.005	0.019	0.006	0.005
Cobalt	mg/l	0.034	0.029	0.034	0.044	0.048	0.074	0.029
Copper	mg/l	0.042	0.042	0.042	0.010	0.362	0.010	0.042
Iron	mg/l	0.646	0.212	0.646	0.002	1.707	0.002	0.212
Lead	mg/l	0.002	0.018	0.002	0.028	0.048	0.022	0.018
Magnesium	mg/l	8	69	8	131	94.7	95	69
Manganese	mg/l	1.08	1.30	1.08	2.00	2.80	2.00	1.30
Mercury	mg/l	0.00019	0.00015	0.00019	0.00015	0.00048	0.00041	0.00015
Molybednum	mg/l	0.3	2.1	0.3	1.8	11.6	2.1	2.1
Nickel	mg/l	0.015	0.061	0.015	0.127	0.048	0.090	0.061
Potassium	mg/l	16	45	16	79	17	125	45
Selenium	mg/l	0.008	0.022	0.008	0.033	0.053	0.032	0.022
Silver	mg/l	0.000	0.002	0.000	0.001	0.010	0.002	0.002
Sodium	mg/l	26	92	26	170	65	176	92
Thallium	mg/l	0.00036	0.00047	0.00036	0.00092	0.00048	0.00076	0.00047
Silicon	mg/l	5	9	5	8	21	18	9
Tin	mg/l	0.001	0.037	0.001	0.031	0.192	0.042	0.037
Vanadium	mg/l	0.001	0.009	0.001	0.005	0.029	0.032	0.009
Zinc	mg/l	0.41	1.30	0.41	2.49	1.86	1.97	1.30
Nitrate_N	mg/l	2.2	2.4	2.2	2.7	4.9	2.5	2.4
Nitrate (ion)	mg/l	10	9	10	9	22	8	9
Nitrite	mg/l	0.19	0.19	0.19	0.18	0.43	0.15	0.19
Ammonia	mg/l	0.2	0.4	0.2	0.4	0.5	1.3	0.4
Hardness as $CaCO_3$	mg/l	146	852	146	1,226	2,230	1,388	852
Flows	cfs	14	29	14	100	18	0	29

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NOTES:

1. MODEL INPUT CONCENTRATIONS PROVIDED BY SRK CONSULTING (DATED 20 JUNE. 2018).
2. TAILINGS POND ADJUSTMENT VALUES WERE APPLIED FOR Al, SO4, Fe, Cu and Mn IN THE BULK TSF AND PYRITIC TSF.
3. TDS VALUES WERE CALCULATED BY SUMMING ALKALINITY, Cl, F, SO_4, Ca, Mg, K, Na AND Si.
4. MODEL ASSUMES RETURN OF SLUDGE AND REJECT FLOWS FROM WTP#1 AND WTP#2 TO THE PYRITIC TSF VIA THE PYRITIC TAILINGS LINE.
5. WTP EFFLUENT, SLUDGE AND REJECT CONCENTRATIONS WERE PROVIDED BY HDR (DATED 4 JANUARY. 2018).
6. HARDNESS VALUES WERE CALCULATED BASED ON THE EQUATION
   HARDNESS ($CaCO_3$) = CALCIUM CONCENTRATION (mg/L)*2.497+MAGNESSIUM CONCENTRATION (mg/L)*4.118
7. THE PERCENTILE RESULTS BASED ON 76 REALIZATIONS OF MODEL SIMULATIONS.
8. MODEL ASSUMES THE LOADING FROM THE PAG WASTE ROCK IN THE PYRITIC TSF AS A FLUSHING TERM PROVIDED BY SRK CONSULTING (DATED 20 JUNE. 2018).
9. MODEL ASSUMES ADDITIONAL LOADING FROM INPIT STOCKIPLE IN THE OPEN PIT DURING THE SUMMER MONTHS.
10. pH WAS NOT MODELLED AND pH VALUES ARE BASED ON THE RANGE OF pH SOURCE TERMS PROVIDED BY SRK (DATED 20 JUNE. 2018).

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